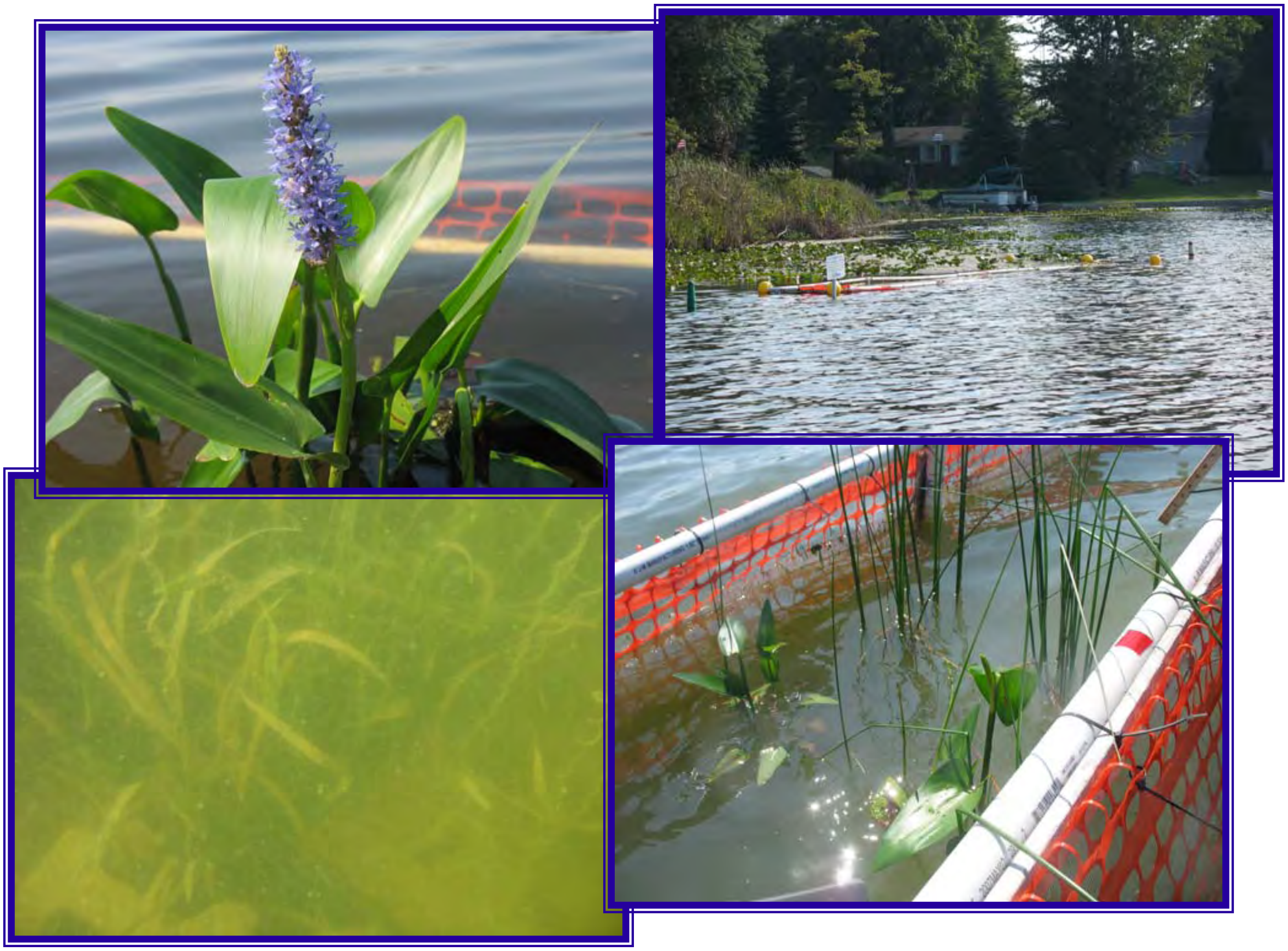
Littoral Zone Restoration Research Project 2007-2009
Year 1 Report

Crooked, Chapman, Tippecanoe, and Wawasee Lakes
Steuben and Kosciusko Counties, Indiana

DRAFT

December 19, 2007



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LITTORAL ZONE RESTORATION RESEARCH PROJECT 2007-2009

CROOKED, CHAPMAN, TIPPECANOE, AND WAWASEE LAKES
STEUBEN AND KOSCIUSKO COUNTIES, INDIANA

DRAFT
YEAR I REPORT

EXECUTIVE SUMMARY

A three year study was initiated to re-establish native vegetation in the littoral zones of four northeast Indiana lakes: Crooked Lake in Steuben County and Lake Wawasee, Lake Tippecanoe, and Chapman Lake in Kosciusko County. Goals for the project were to research past restoration projects to establish the current knowledge base; design four treatments to re-establish vegetation; and evaluate each treatment in each lake and overall. The following tasks were completed during Year 1: a literature search of previously-completed in-lake planting projects, techniques, and evaluations of success; a review of treatment lakes to determine appropriate treatment locations; investigation of historic plant community structures within the treatment lakes; and public meetings at each of the four lakes.

Each treatment consisted of 36 plants installed within a 1-square meter area. The four treatments included: vegetation that were directly planted into the lake bottom substrate, vegetation planted into an coconut erosion control mat that was attached to the lake bottom, vegetation installed inside a small concrete donut placed at the lake bottom, and vegetation installed into a wooden pallet filled with soil and then placed on the lake bottom. Projects were installed in each lake during the week of June 18, 2007 and were monitored on a weekly basis by a lake volunteer for structural integrity and water clarity. In August 2007, JFNew field personnel evaluated plant species survival and growth.

Overall, survival of each plant species varied by treatment type within each of the four lakes. The concrete donut treatment type was the most productive in terms of survival of planted individuals, followed closely by the wooden pallet treatment. The direct planting treatment contained the third highest survival rates. The lowest survival rates were observed in plants installed using the erosion control mat treatment. It is possible that the erosion control mats were not securely installed in the substrate, leading to movement and folding of the mats, and subsequent mortality of planted individuals. Data suggest that a more structurally sound medium for planting will result in better survival of planted individuals, especially where there is greater wave action. In general, plant height and length increased from the time of planting to the time of sampling. Some species showed impressive growth (130 to 5000% increase in height) during the growing season. The fact that the height/length was greater during the sampling inspection than at the time of planting shows that the structures are likely reducing herbivory, and that mortality is likely due to another cause.

ACKNOWLEDGEMENTS

The Littoral Zone Restoration Research Project was made possible with funding from the Indiana Department of Natural Resources (IDNR) Division of Fish and Wildlife. The Littoral Zone Restoration Research Project was completed by JFNew with assistance from the Crooked Lake Association, Chapman Lake Conservation Association, Lake Tippecanoe Property Owners, and Wawasee Area Conservancy Foundation. Contributors to this study included Jed Pearson, Neil Ledet, Stu Shipman, Angela Sturdevant, and Gwen White with the IDNR Division of Fish and Wildlife. Special thanks to the dedicated members of the above referenced lake associations for their initiative and assistance in getting this study completed. Area residents who completed weekly monitoring throughout the summer and participated in the study design included: Keith Hoskins, Crooked Lake Association; Kathy Kostro, Bill Magurany, and Len Draving, Chapman Lake Conservation Association; Holly LaSalle and Megan Ennis, Lake Tippecanoe Property Owners; and Heather Harwood, Wawasee Area Conservancy Foundation. Thanks also to everyone who assisted with the project set-up, project design, and treatment installation including: Stu Shipman, Gwen White, Neil Ledet, Angela Sturdevant, and Jed Pearson, IDNR-DFW; Shaun Warkentin, Chris White, Aaron Johnson, Mark Pranckus, Scott Namestnik, John Richardson, and Sara Peel, JFNew; Keith Hoskins, Crooked Lake Association; Dan Lee and Bill Magurany, Chapman Lakes Conservation Association; and Heather Harwood, Wawasee Area Conservancy Foundation. Authors of this report included Sara Peel, Scott Namestnik, Betsy Ewoldt, John Richardson, and Mark Pranckus at JFNew.

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CROOKED, CHAPMAN, TIPPECANOE, AND WAWASEE LAKES
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YEAR I REPORT

1.0 INTRODUCTION

1.1 Background

The Crooked Lake Association requested the assistance of JFNew in 2004 to restore vegetation to a former "island" or shallow water area in the center of the lake which had once been dominated by hardstem bulrush. JFNew had been working with several other lake associations who also expressed interest in restoring or enhancing native plant communities within their lakes. With the commitment of the Crooked Lake Association to proceed with a revegetation project, JFNew facilitated the application for a joint Lake and River Enhancement Grant between four lake associations: the Crooked Lake Association, Chapman Lake Conservation Association, Lake Tippecanoe Property Owner, and Wawasee Area Conservancy Foundation. The application for funding proposed identical plant restoration treatments in each of the respective lakes that would allow statistically valid analysis of certain variables between lakes to document reasons for the success or failure of the re-plantings over a three year monitoring program. Each of the four project lakes (Crooked Lake in Steuben County and Chapman, Tippecanoe, and Wawasee lakes in Kosciusko County) identified areas where emergent and rooted floating aquatic vegetation had once existed but was no longer present. In each area, wind and wave action, water quality impacts, and anthropogenic factors, such as skiing and personal watercraft use in these areas, were thought to be the contributing factors to the loss of this vegetation. The LARE program funded the project in 2006 with the Crooked Lake Association acting as the grant administrator. A contract was signed with JFNew in late 2006 to implement the project. Each of the participating lake associations also signed contracts that cover specific duties including input on the design of the treatment types, location of the treatment area, and weekly monitoring of the structure and associated water quality.

1.2 Scope of Project

The scope of this project included all items necessary to develop a statistically-valid, experimentally-based restoration project for Crooked, Chapman, Tippecanoe, and Wawasee lakes. Specifically, the scope included the following:

- a literature search to identify previous in-lake planting projects, techniques, and success rates;
- an investigation of the treatment lakes to determine appropriate experimental restoration locations and document the status and nature of the selected treatment area within each lake prior to installation;
- development of a statistically-valid design to be installed within each lake;
- installation of the four pre-determined techniques within each of the four treatment lakes;
- establishment of a project steering committee to oversee project development and assist with on-lake information distribution;
- weekly structure and water quality monitoring by volunteers;

- quarterly structure monitoring by JFNew;
- annual aquatic plant monitoring following a standard and repeatable protocol;
- acquisition of all necessary permits prior to project installation;
- public outreach through the development of lake-specific informational handouts and public meetings; and
- annual progress reports and an end of project final report.

Geographically, this project includes four lakes: Crooked Lake in Steuben County and Chapman Lake, Lake Tippecanoe, and Lake Wawasee in Kosciusko County (Figure 1).

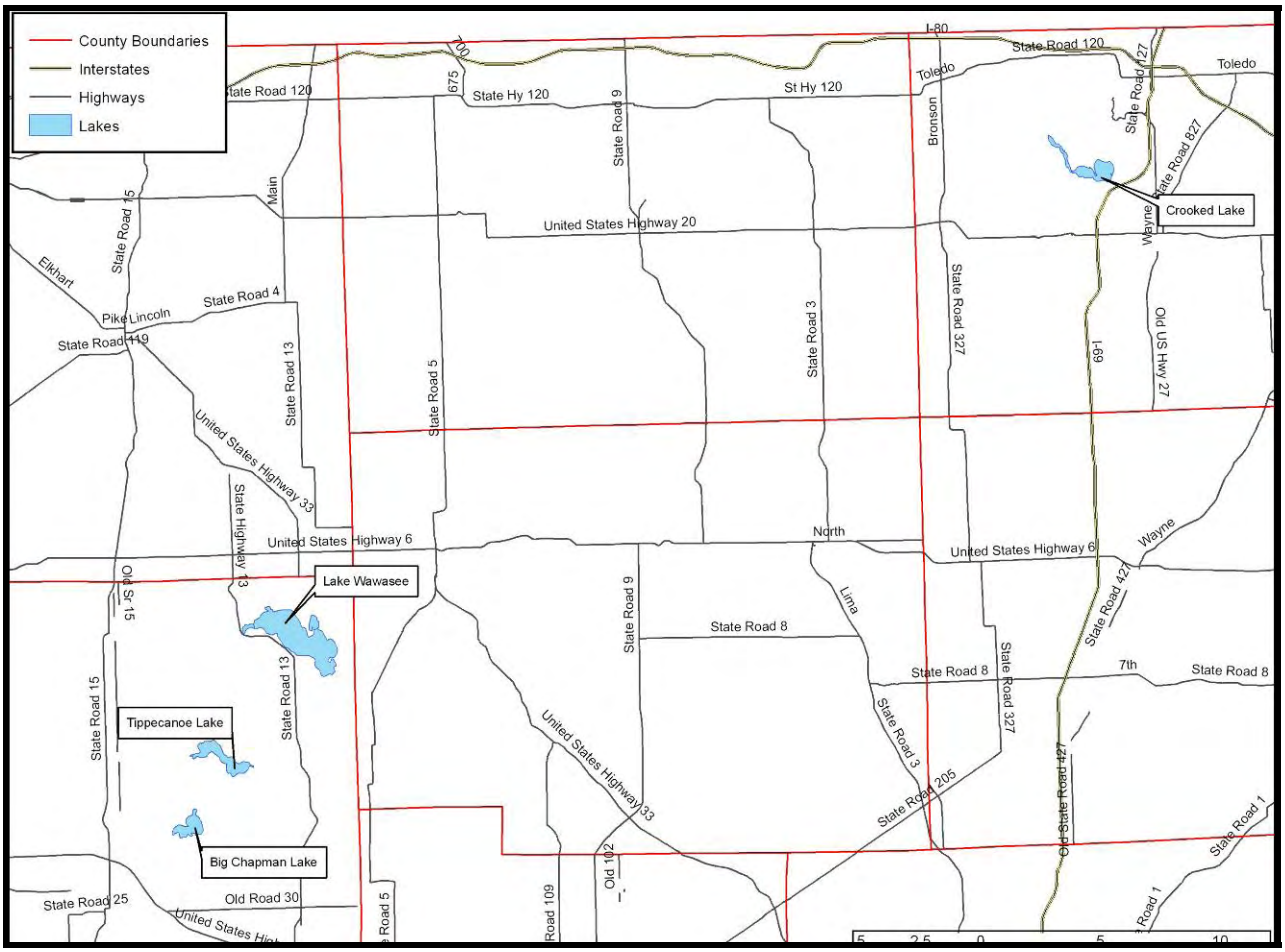

Figure 1. Lakes included in littoral zone restoration research project.

1.3 Goals and Objectives

The goal of the project is to develop and evaluate methods to successfully establish plants within open water (littoral) environments within Crooked Lake (Steuben), Lake Wawasee, Lake Tippecanoe, and Chapman Lake. The secondary objective is to restore aquatic vegetation within the selected 10 square meter treatment location.

2.0 HISTORIC RESEARCH

2.1 Historic Littoral Zone Restoration Projects

Prior to design and construction, JFNew conducted a review of the available literature on aquatic plant restoration. Littoral zone restoration projects have been conducted in many areas; however, a majority of these projects did not include any post-planting monitoring. Of those that did monitor the plantings, few included a control plot for comparison and many have not released their results. Consequently, the success/failure rate for littoral zone restorations is not well-documented. A quick web search of communities and groups that have attempted littoral zone restorations indicates a high success rate but this may be because groups that did not observe successful vegetation establishment did not publicize their project. Data from monitored and documented projects exhibit a mixed-bag of results. A review of the U.S. Fish and Wildlife Service's Partners for Fish and Wildlife program in Wisconsin, which provided the largest dataset of restoration results, suggests in approximately equal numbers of low, medium, and high-quality vegetation communities after planting. This study did not include comparison to any control areas so it is unclear if the plantings were the cause of any improvements or if they were the result of successional processes.

Despite the sparse documentation, some general guidelines for restoration design emerged from the literature and case studies. Choices of planting locations tend to focus on the availability of light and the consistency of the substrate. Ideal planting sites contain ample light (sites are usually planted to the 1% light level) and a substrate with organic content less than 5%. Preferred species vary based on individual site locations; therefore, many sources recommend choosing plants found in neighboring lakes or documented in historical studies. Furthermore, research indicates that past restoration efforts focused on a core group of factors to plan and locate planting areas. These factors include: light availability, substrate, wave action, and water level fluctuation. The following sections detail specifics with relation to these factors. The annotated bibliography in Appendix A details other studies reviewed prior to beginning the Littoral Zone Restoration Research Project.

Light availability is the key factor in aquatic planting projects and has been used extensively in project planning to determine the optimal location for plant installation. In general, the 1% light level was used to determine the maximum planting depth. Specific studies utilized light levels, and specifically the 1% light level, in a variety of ways. In one study, the 1% light level overestimated the lower planting depth limit with plant growth limited to between the 10% and 20% light levels (Chambers and Kaliff, 1985). Middelboe and Markager (1997) studied 153 lakes and discovered a wide range in the minimum plant depth. Variations could be explained by both differences between plant species and differences in lake characteristics. Despite the variation, the 1% light level has remained the general guideline used in littoral zone restoration projects

Most documented projects cited substrate as an important factor in determining plant growth but information has been scarce on how substrate actually affects the plants. Part of the confusion has arisen due to the number of factors associated with substrate that could affect project success. Texture (Barko and Smart, 1996; Koch, 2001; Weisner, 1987; Weisner, 1991), organic matter content (Barko and Smart, 1996; Koch, 2001), and slope (Hawes et al., 2003) have all been used to explain limitation of growth. How each of these factors affects different species or types of plant can also vary, complicating the matter even more.

Of the substrate characteristics, texture may play the largest role in determining the probability of plant growth. A majority of the reviewed studies cited substrate texture as a determining factor of plant growth. Lower growth rates have been documented on sandy substrates and mucks (Barko and Smart, 1986). In both substrates, nutrient limitation was used to explain the diminished growth. Sands naturally contain low nutrient concentrations. Additionally, nutrients bind to the organic matter in mucks, making those nutrients unavailable to plants. After excluding those substrates, not much consensus could be found on an optimal texture and variation is likely between different species. In general, a substrate must provide both stability and nutrients.

Wave action can also inhibit plant growth. The primary mechanism of this inhibition is attributed to the shifting of substrate. Wave action can scour the planting area, removing sediment from the base of the plants, or deposit sediment, burying the plants. Either scenario can inhibit plant growth or cause recession among already established plant beds. Additionally, wave action can increase turbidity, thereby negatively affecting the light availability in an area. As such, most aquatic plant restoration projects have accounted for lake fetch or have been located in sheltered locations, such as bays.

While most aquatic plants can endure large water level fluctuations when established, those fluctuations have been cited as potential reasons for failure among newly planted restoration beds. In addition, most established aquatic plant beds can endure some level of herbivory, but carp, waterfowl, turtles, and muskrats can cause restoration failure if they get in before plants get properly established.

Once suitability has been ensured, the primary obstacles to establishment tend to be herbivory and water level fluctuation. Herbivory is typically limited through the use of exclosures. The effect of fluctuating water levels is typically limited by taking fluctuations into account during site selection and choosing plants that can tolerate the typical range of water levels at a particular depth. In some cases, wave action can be a consideration. When considered, planting areas were protected by coir logs (biologs) or breakers placed in front of the planting zones. Despite the presence of general guidelines, much of the design process depends on the specific site requirements and goals of the project. For example, actual recommended planting depths depend on the species used and substrate on-site, which in turn depend on the location of the lake and goals of the project.

Restoration of littoral zone vegetation has been attempted by numerous lake associations, towns, and other citizen's groups. The majority of these projects focused more on education and volunteer participation than on actual results. As a result, most projects have not included any post-planting monitoring or documentation of techniques and results. Of those groups that did monitor the plantings, few included a control plot for comparison and many have not publicly released their results. Consequently, the success rate for littoral zone restoration techniques is not well-documented, especially over the long-term (five years after planting or more). Analysis of the few studies that included monitoring (Hellsten et al., 1996; Smart et al., 1998; Burdick et al., 2004; Dick et al., 2004 a, b, c) found that short-term (five years or less after planting) success rates were highly variable. The few sites monitored after five years (Dick et al., 2004a) found low survival rates. However, no maintenance activities were implemented at these sites, which allowed herbivores to breach the exclosures.

In general, an effective littoral zone planting requires two aspects. First, the plan must take into account the site-specific requirements of the lake and match the plants to the lake. Second, all potential impairments to plant growth (high turbidity, herbivory) must either be reduced within the lake or accounted for through the use of structures such as exclosures.

2.2 Historic Plant Communities

2.2.1 Crooked Lake

Historically, Crooked Lake contained a diverse aquatic plant community. In 1966, soft rush (*Juncus effusus*) was noted to be the most dominant emergent species (likely misidentification of bulrush), where it was noted to grow in two isolated patches in the First and Second Basins of the lake. Hudson (1967) noted that the remaining emergent vegetation in these basins was "unimportant." Nonetheless, nine emergent and rooted floating species and ten submerged species were identified within Crooked Lake during the 1966 assessment. (Aquatic plant species identified within Crooked Lake historically are detailed in Appendix B). Peterson (1973) identified seventeen species within the first basin during the 1972 assessment (Appendix B). This species survey documented aquatic plants representing each of the three strata (submerged, emergent, and floating). A map included with this report indicated the location of the emergent plant community on the submerged island within Crooked Lake's First Basin. Subsequent surveys document similar plant communities; however, Indiana Department of Natural Resources (IDNR) fisheries biologists noted only twelve species during their 1978 survey (Peterson, 1979). A total of 22 species were identified throughout the lake during the 2001 survey (Ledet, 2002). Aquatic Control (2007) identified 24 species during Tier I and Tier II LARE-funded aquatic plant surveys completed in the spring and summer of 2006. Throughout this time span, it is likely that the aquatic plant community changed little despite the differing diversities; rather, it is likely that different survey methodologies account for the variation if plant diversity.

2.2.2 Chapman Lake

IDNR fisheries surveys record brief descriptions of the rooted plants in Chapman Lake. A 1964 survey (McGinty, 1964) reports "extensive areas without aquatic vegetation" in Big Chapman Lake. It noted that the manmade channels supported the densest macrophyte growth. Dominant submerged species included coontail, bushy pondweed, elodea, milfoil, and chara. The report lists soft rush as the dominant emergent, although it is likely that this is a misidentification of bulrush. A decade later, an IDNR Fisheries Survey (Shipman, 1976) highlighted the relatively low productivity of the lake. Bulrush, cattails, and milfoil dominated the lake according to this survey. The report reiterates that vegetation is of concern in the channels. Surveys conducted in the 1990's (Pearson, 1991 and 1999) found similar dominant species as those listed in the 1976 survey. The reports note an increased abundance of curly-leaf pondweed, but again large areas of unvegetated shallows existed at the time of survey. Purple loosestrife was first noted in the 1991 survey. Submerged plant density in the channels remained a concern. (Appendix B provides a complete list of macrophyte species found in historical surveys on Big Chapman.)

A diverse mix of native pondweeds, eel grass, and emergent vegetation grows in patches throughout Big Chapman Lake. The lake is also characterized by large expanses of shallow water in which rooted plant growth is absent. Because in-lake sampling suggests sufficient light is present for the establishment of rooted plant growth throughout much of Big Chapman Lake, growth is likely limited by the marl and sand substrate in many portions of the lake. This substrate may not provide enough nutrients to support dense vegetative growth. JFNew (2000) noted that the heaviest plant growth was noted in the channels and Nellie's Bay. The muck substrate in these areas provides a rich nutrient source for plants. Nuisance levels of Eurasian water milfoil are limited to the channels and the eastern shoreline. During the most recent assessments, JFNew (2007) identified approximately 50 aquatic species within Big Chapman Lake.

2.2.3 Lake Tippecanoe

Like other lakes previously discussed, Lake Tippecanoe contains a diverse aquatic plant community. The first documented aquatic plant survey occurred on the lake in 1976, at which time the DNR noted eighteen aquatic plant species throughout the lake chain (Lake James, Oswego Lake, Lake Tippecanoe; Shipman, 1977). Subsequent surveys identified fewer species. Fifteen species were identified in 1995 (Pearson, 1995) at which time, Pearson noted that emergent species were relatively sparse throughout the lake. Pearson further indicated that emergent species occurred in isolated patches throughout the lake (Pearson, 1995). Aquatic Control (2005) documented 25 submerged species that were identified within the Tippecanoe Chain in 2002, 2003, and 2004. Aquatic Control also detailed aquatic plant management history within Lake Tippecanoe. (Aquatic plant species identified within Lake Tippecanoe historically are detailed in Appendix B.) During surveys completed in 2005, Aquatic Control identified ten submerged species in Lake Tippecanoe (Aquatic Control, 2006). In 2006, similar surveys indicate that fourteen submerged species were present in Lake Tippecanoe (Aquatic Control, 2007). The IDNR indicated concern over the relatively sparse aquatic plant community present throughout the lake and suggested that shoreline property owners should minimize alterations to the shoreline (Pearson, 2007). Pearson further suggested that owners should restore native plants, install natural boulders, and control nuisance invasive species but leave native plant beds intact. Additionally, Pearson (2007) noted the presence of isolated patches of spatterdock and white water lilies throughout the lake.

2.2.4 Lake Wawasee

Shipman (1975) identified a variety of aquatic plants in Lake Wawasee during the DNR's initial aquatic plant survey of the lake in 1975. At that time, 17 aquatic plant species representing all three strata (submerged, emergent, and floating) were present within the lake. (Aquatic plant species identified within Lake Wawasee historically are detailed in Appendix B.) Shipman (1975) also indicated that aquatic plants within the man-made channels surrounding Lake Wawasee posed continuous problems for lake residents and stated that the wetland vegetation present within Conklin and Johnson Bays should remain "as intact as possible to protect and preserve water filtration and fish spawning habitat". Subsequent surveys in 1985 indicated that Lake Wawasee contained a diverse aquatic plant community where coontail, elodea, and milfoil dominated the submerged species. Dense cattail and purple loosestrife stands were noted within Conklin and Johnson Bays and around the mouth of Turkey Creek (Pearson, 1986). During surveys completed in 2004, the DNR identified seventeen aquatic plant species (Fink, 2005). Subsequent surveys completed by V3 included identification of nineteen submerged species throughout Lake Wawasee (V3 Companies Ltd, 2007).

3.0 PROJECT PLANNING

3.1 Location Assessment

Prior to the planting, JFNew biologists met with each lake representative to select the planting site and perform preliminary sampling at the site. The sampling included assessment of Secchi disk reading and light level at the deepest part of the lake; description of the substrate at the selected site; collection of a sediment sample for laboratory analysis; documentation of existing plant communities and species present in April, which is prior to when most species are identifiable in Indiana lakes; observation of fauna present during the survey; determination of water depth and slope of the substrate across the 10 meter long planting zone; and observation of adjacent shoreline characteristics. The visual observations of the bottom were completed using snorkel gear, while the substrate was collected using a 1.5-inch diameter PVC pipe inserted into the substrate from 6 to 12 inches. To collect the sample, the pipe was inserted into the sediment, and then capped. The PVC pipe was pulled from the water before removing the cap and allowing the sediment to flow into a 1.0 liter laboratory-provided collection jar. The collected samples were analyzed for total phosphorus and total nitrogen by EIS Analytical in South Bend, Indiana and for percent solids and overall composition by Shilts and Graves in South Bend, Indiana. Appendix C contains copies of the laboratories' findings. The following sections detail findings from the investigations completed on each lake in April 2007.

3.1.1 Crooked Lake

The selected area was located in unprotected open water approximately 500 feet (152.4 m) off the shoreline within the First Basin of Crooked Lake (Figure 2). The closest shoreline consisted of residentially improved land covered by concrete seawalls. Boat traffic and wind from all directions likely cause significant wave action at the site. Additionally, the area serves as a recreational sandbar for basin water sports activities and is a popular destination during the height of the summer boating season. A preliminary survey of Crooked Lake on April 19, 2007 documented a Secchi disk transparency of 15 feet (4.6 m) at the deepest part of the lake. At the selected project site, the water depth measured 2.8 to 2.9 feet (0.85 to 0.88 m) with 36% of the available light present at the bottom. The substrate was sand and less then 5% cover of filamentous algae was present during the April assessment. No other plants were visible during the assessment. Additionally, no fauna were observed within the area of the site. The bottom slope was 0.005 (less than one-half of 1 percent) across the selected treatment area. The analyzed sediments contained 3.1% fine gravel, 93.7% sand, 1.2% silt, 2.0% clay, and 0.8% organic matter. Total phosphorus measured 110 mg/kg and total nitrogen measured 1080 mg/kg (both are wet weights).

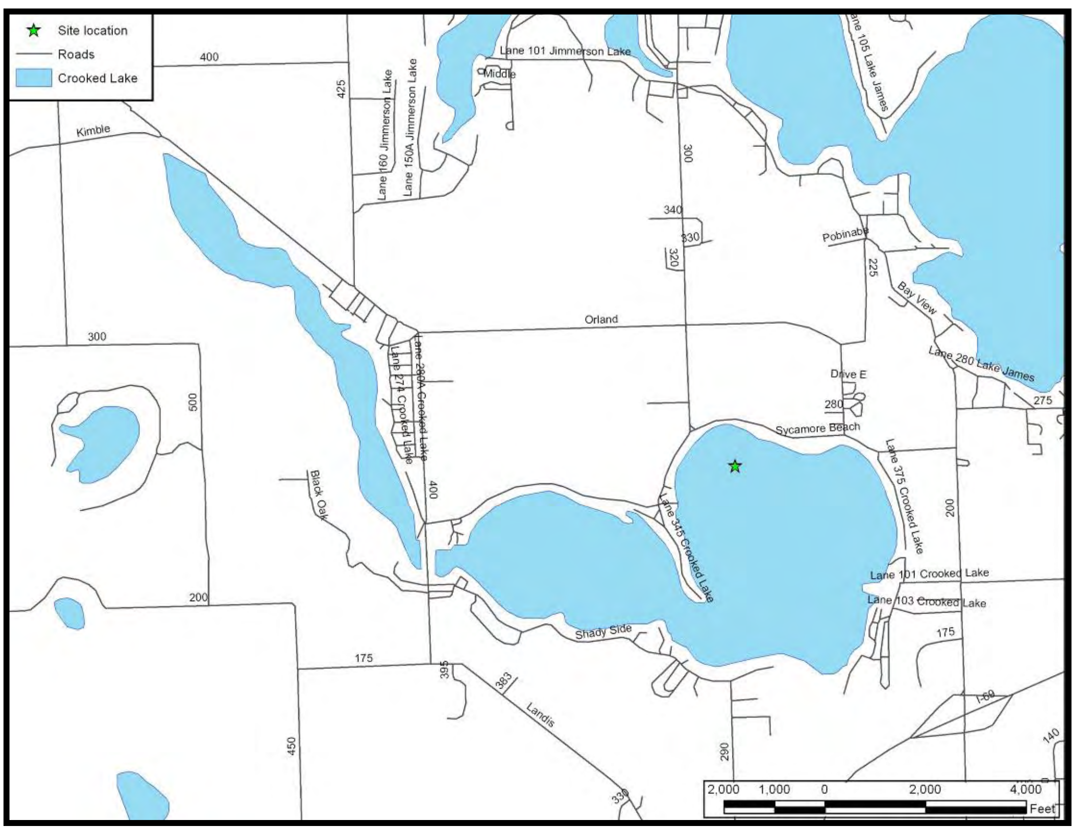

Figure 2. Restoration research location within Crooked Lake.

3.1.2 Chapman Lake

The selected area was exposed to significant wave action being just 50 feet (15.2 m) off a concrete seawall-lined shoreline near Hog Point (Figure 3). The site is located on the north side of the Big Chapman Lake with approximately 1 mile (1,609.3 m) of open water located to the south. This area generally serves as a recreational spot for boaters to park their boats and swim during the summer. A preliminary survey of Chapman Lake on April 18, 2007 documented a Secchi disk transparency of 6 feet (1.8 m) at the deepest part of the lake. The depth of the water at the project site measured 2.0 feet (0.6 m) and 29% of the available light was present at the bottom. The substrate was sand and marl with approximately 15% cover of filamentous algae as the only plants visible. Red worms and zebra mussel shells were observed within the area of the site. The bottom slope measured 0.005 (one-half of 1 percent) across the selected treatment area. The analyzed sediments contained 3.3% fine gravel, 39.2% sand, 38.9% silt, 18.6% clay, and 6.7% organic matter. Total phosphorus was 13 mg/kg and total nitrogen was 1850 mg/kg (both are wet weights).

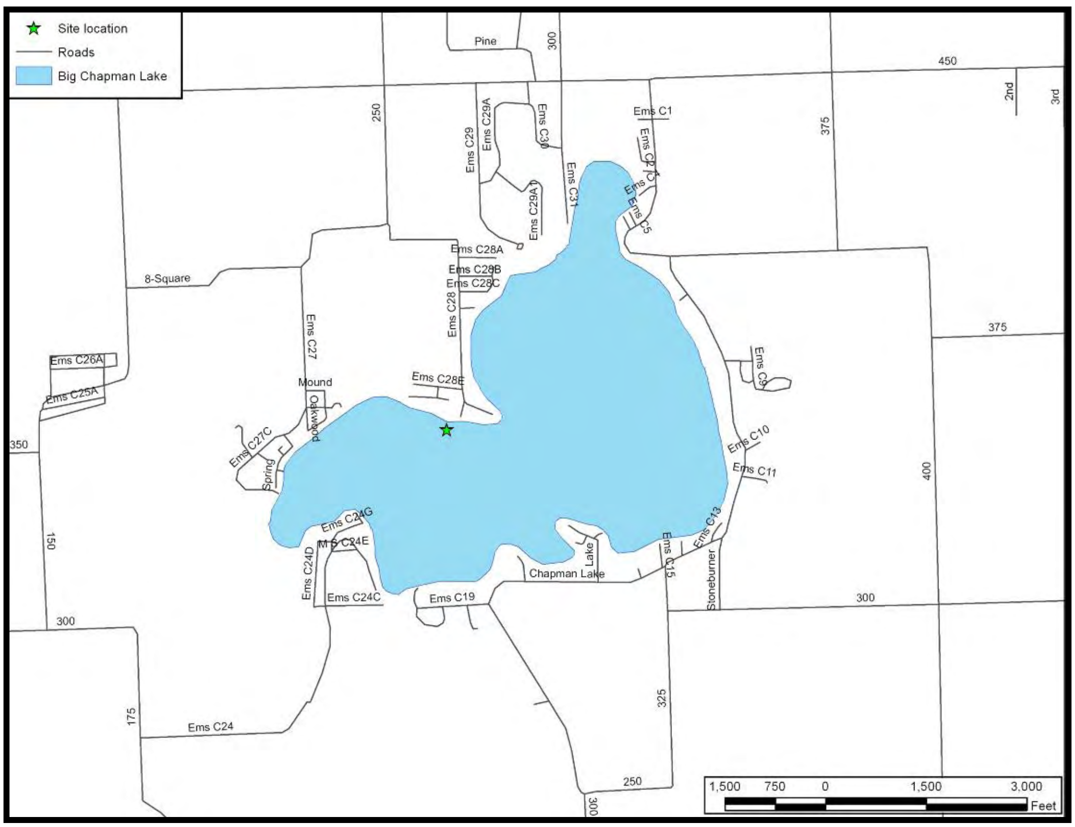

Figure 3. Restoration research location within Chapman Lake.

3.1.3 Lake Tippecanoe

The selected area was somewhat protected as it is located 30 feet (9.1 m) off the shoreline of the Ball Nature Preserve and is near an existing 10 mph zone for entrance into the channel between Lake Tippecanoe and Lake James (Figure 4). Winds from the west may cause significant waves in addition to the boat traffic funneling through the channel nearby. Additionally, this shallow, protected area is a popular skiing area for lake users. A preliminary survey of Lake Tippecanoe on April 18, 2007 documented a Secchi disk transparency of 10 feet (3.1 m) at the deepest part of the lake. The depth of the water at the project site measured 2.95 to 3.1 feet (0.90 to 0.94 m) and 28% of the available light was present at the bottom. The substrate was comprised of sand and marl. The site contained nearly 100% cover of filamentous algae. No fauna were observed within the area of the site. The bottom slope was 0.005 (one-half of 1 percent) across the selected treatment area. The analyzed sediments contained 8.5% fine gravel, 61% sand, 19.5% silt, 11% clay, and 5.2% organic matter. Total phosphorus measured 82 mg/kg and total nitrogen measured 2040 mg/kg (both are wet weights).

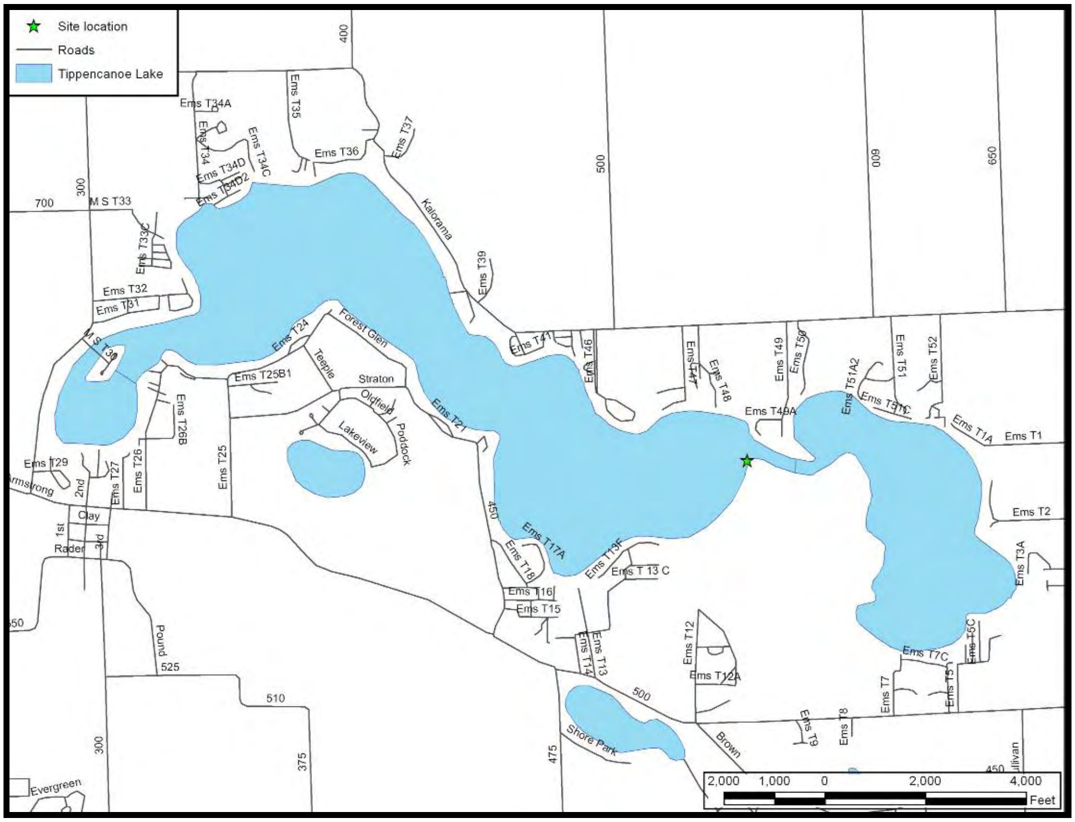

Figure 4. Restoration research location within Lake Tippecanoe.

3.1.4 Lake Wawasee

The selected area is located within Conklin Bay on the northeast side of the lake and is somewhat protected being located 20 feet (6.1 m) off of a vegetated shoreline (Figure 5). However, boat traffic from adjacent channels, which are populated by 50 residents each, increases wave action at the site. Winds from the south may cause some additional wave action; additionally, this area does experience significant recreational boating activity. A preliminary survey of Lake Wawasee on April 18, 2007 documented a Secchi disk transparency of 16.5 feet (5.0 m) at the deepest point of the lake. The depth of the water at the project site measured 2.8 to 3.0 feet (0.85 to 0.91 m). Additionally, 15% of the available light was present on the bottom at the selected site. The substrate was sandy marl over peat. The site contained approximately 20% cover of filamentous algae; one white water lily was the only plant visible. Zebra mussel and freshwater unionid shells were observed; however, no live specimens were observed within the area of the site. The bottom slope was 0.01 (1 percent) across the selected treatment area. The analyzed sediments contained 4.0% fine gravel, 89.9% sand, 3.0% silt, 3.1% clay, and 7.7% organic matter. Total phosphorus measured 110 mg/kg and total nitrogen measured 4580 mg/kg (both are wet weights).

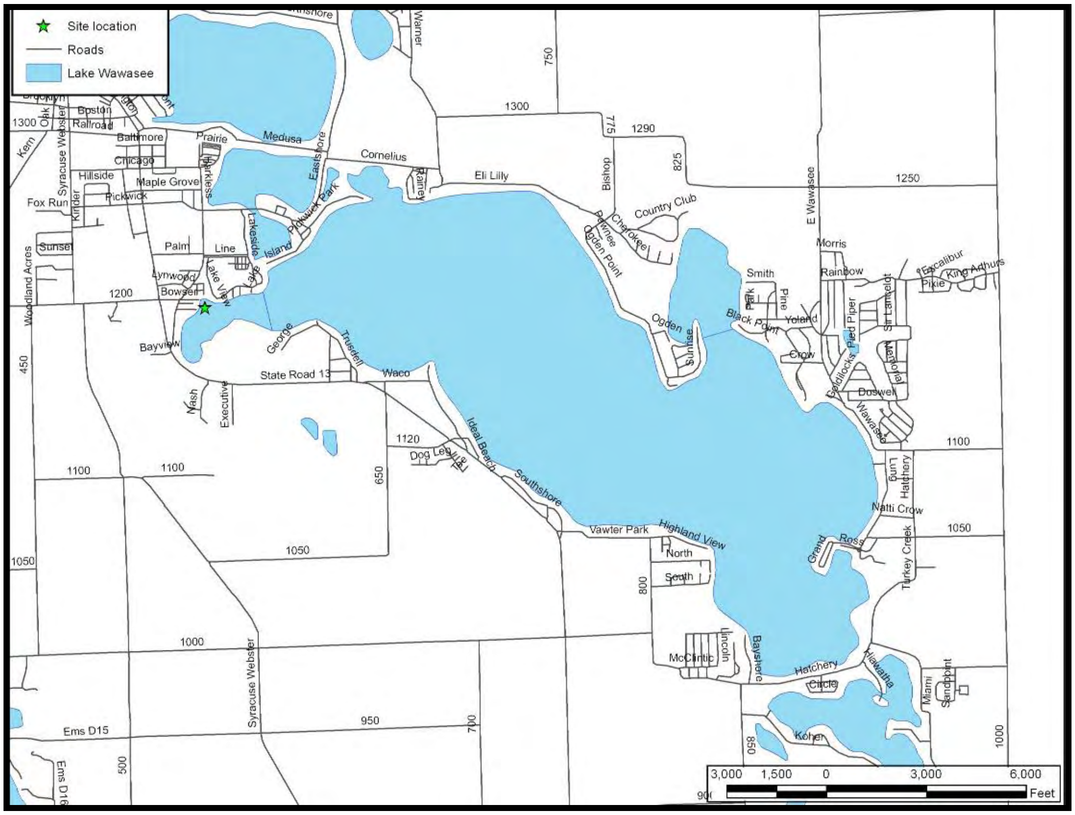

Figure 5. Restoration research location within Lake Wawasee.

3.2 Permitting

Planting directly into the substrate of a lake or wetland does not require any permits as long as no mechanized equipment (generally meaning no motor operated equipment) is utilized in the process. Since the experiment designed by JFNew included an exclosure, it required a Public Freshwater Lake permit from the Division of Water within the Indiana Department of Natural Resources (IDNR). During the review process for the permit, which included a public notice to the landowners adjacent to the proposed structure locations, no public resistance was discovered. Concerns were raised by the DNR Division of Law Enforcement (DLE). Specific concerns identified by the DLE indicate that since the structure is a navigation hazard, the DLE required the installation of navigational marking buoys around the structure. Additionally, the DLE required that the structure be dismantled each winter to prevent snow machines from hitting the structure. Ultimately, the Division of Water granted the permit with the above conditional changes. Copies of the final permits are included in Appendix D.

3.3 Planting Design

3.3.1 Aquatic Plant Selection

Nine species of aquatic plants representing all three strata (submergent, floating, and emergent) were identified for planting. The selected species were all historically present in all four lakes and included eel grass (*Vallisneria americana*), grassy pondweed (*Potamogeton gramineus*), Illinois pondweed (*Potamogeton illinoensis*), common waterweed (*Elodea canadensis*), water shield (*Brasenia schreberi*), white water lily (*Nymphaea tuberosa*), chairmaker's rush (*Scirpus acutus*), hard-stem bulrush (*Scirpus pungens*), and pickerel weed (*Pontedaria cordata*). The plants consisted of bare root stock or 2.5-inch (6.4-cm) diameter by 4-inch (10.2-cm) long nursery-grown plugs. All plants were photo-documented prior to pre-planting (Appendix E). Additionally, all plants had at least three months of growth prior to being installed in the lake and were in a healthy condition at the time of installation. Four plants of each of the nine species were utilized for each treatment type for a total of 36 plants per treatment. Since there were four treatment types as detailed below, a total of 144 plants were installed in each lake.

3.3.2 Treatment Types

Four active methods of plant installation were developed by JFNew for attempting to hold the plants within the substrate. Each treatment method covered one square meter within each lake. Design specifications and photographs of each of the planting techniques are included in Appendix F and G, respectively. The same four treatment methods and number of plants were utilized in each of the lakes. The four methods were as follows:

- Method 1: Direct planting of the 36 plants into the substrate utilizing 1-inch by 6-inch sod staples to secure the plant to the bottom.
- Method 2: Planting of plugs and bare root specimens directly into a coir fiber pillow and then securing the mat to the substrate using 1-inch by 12-inch steel staples (6-8).
- Method 3: Constructing four 50 cm by 50 cm by 10 cm wooden pallets with defined 8 cm by 8 cm opening for each of nine plants. Four of these pallets formed a one meter square treatment and contained 36 plants.
- Method 4: Manufacturing a concrete container system for each plant (36) for each square meter treatment. The concrete container resembled a donut with a total diameter of approximately 10 cm and an inside hole diameter of approximately 4 cm. The thickness or height of the donut structure was approximately 5 cm. A hardware cloth tube (mesh size openings of 0.5 cm) was inserted into one end of the concrete donut during the manufacturing process to support the plug or bare root plant. This hardware cloth extension was driven into the substrate so that the top of the concrete structure was even with the substrate.

Two controls were established as part of this project as well. The first control is located within the exclosure structure. This control was included to allow researchers to determine whether protection from the open water environment would allow for plants to grow without any pre-planting required. The second control is outside of the exclosure and serves as an example of the routine environment within each of the lakes. Each control measures 1 square meter (9.6 sq ft). Additionally, four unplanted plots (1 square meter each) exist within the 10 meter by 1 meter (32.8 ft by 3.1 ft) exclosure. An unplanted area remains between each of the planted treatments in order to monitor any migration of the plants outside of the square meter treatments within the protective exclosure. The outside edges of the exclosure also act as a control and are monitored for expansion of the plant communities outside of the exclosure.

3.3.3 Exclusion Structure

The exclusion structures measure 32.8 feet (10 m) long, 3.1 feet (1 m) wide, and 4 feet (1.2 m) high. (Appendix E details design of the structures.) They consist of a frame constructed of 1.5-inch (3.8-cm) diameter PVC pipe and hardware cloth (mesh opening 0.125 in or 0.318 cm). There are eight vertical PVC posts spaced 8.2 feet (2.5 m) along the 32.8-foot (10 m) length of the structure. These vertical posts were driven approximately 2 to 4 feet (0.6 to 1.2 m) into the substrate with connectors to the horizontal structures for rigidity. The top of the structure is completely framed by PVC. The hardware cloth was cut into two 3.3-foot (1 m) long and eight 8.2-foot (2.5-m) long sections and stapled to wooden slats (0.4 in thick by 1.2 in wide by 3.2 feet long or 1 cm thick by 3 cm wide by 1 meter long) placed along each edge. The wooden slats were then pre-drilled to receive cable ties on approximately 3.9-inch (10 cm) spacing. Each hardware cloth panel was then secured to the PVC frame horizontal and vertical posts and to the adjacent panel using a minimum of 16 plastic cable ties per panel. The structures extended 2 to 8 inches (5.1 cm to 20.3 cm) of clearance above the water level after installation. Figure 6 displays a typical structure installed during Year 1 of the project.

Figure 6. Completed exclosure structure immediately following installation.

All four exclusion structures were marked to increase visibility in several ways. The entire PVC and hardware cloth frame was the wrapped with high visibility orange snow fence which was then stapled to the wooden structure and cable tied to the PVC frame. A sign was posted on a PVC post adjacent to each structure briefly describing the project and provided a contact for additional information. Two navigational buoys were cabled to 12-inch (30.5 cm) wide concrete blocks and sunken into the substrate (one on either side of the structure). The navigational buoys were cylinder type buoys measuring approximately 2.5 feet (0.8 m) high and rode approximately 1.5 feet (0.5 m) above the water line. A minimum of four 6 to 8-inch (15.2 to 20.3 cm) inflated yellow ball-type buoys were tied or cabled to the structure itself. Additionally, reflective tape was applied to each end and at several places along each side of the PVC frame above the water line. Visibility was at least 165 feet (50 m) and some structures could be seen from across the lake without visual aids (a distance of several hundred feet).

4.0 PROJECT INSTALLATION AND MAINTENANCE

4.1 Initial Planting

All planting occurred June 18 to 21, 2007 with Chapman Lake planting occurring on June 18, Lake Tippecanoe planting on June 19, Crooked Lake planting on June 20, and Lake Wawasee planting on June 21, 2007. Project construction followed a similar pattern in each lake. The PVC structure was installed initially followed by the connection of one long side (10 meters) and one short side (1 meter) of the exclosure structure. Subsequently, one team consisting of two individuals continued exclosure construction, while the second team of two individuals began treatment installation. In all cases, the direct planting occurred first, followed by planting into the coconut mat, installation of the concrete treatment, and finally, placement of the wooden treatments. Plantings began 1.6 feet (0.5 m) from the end of the exclosure; treatments were equally spaced 3.1 feet (1 m) apart with expansion zones located within each 3.1 foot (1 m) unplanted area between treatments. Following installation of the plant treatments, the final piece of the exclosure was attached and the entire structure was covered by snow fence.

4.2 Volunteer Monitoring

Each lake association identified an individual to serve as the representative for their lake to the project committee and as the volunteer monitor for the length of this project. Each volunteer monitored the plot weekly from two weeks following planting through September 2007. Volunteers were instructed to monitor the condition of the exclosure, the general health of the plants, and to measure the Secchi depth at the deepest point of the lake. JFNew provided a datasheet to all volunteers to record their observations and notes. (See Appendix H for a copy of the volunteer monitoring datasheet.) After monitoring, volunteers sent the datasheets electronically or as a hard copy to JFNew where they were transferred into an Excel spreadsheet. If any damage to the exclosure was observed that required repair, the volunteers were instructed to contact JFNew immediately so repairs could be made.

All volunteers maintained a weekly monitoring through the point in October when they removed their boat from the lake or the last week in October, whichever came later. Between August 19 and August 25, nearly 8.5 inches (21.6 cm) of rain fell in the region during several large storms. As a result, many of the lakes rose noticeably, making boating dangerous. As a result, gaps in monitoring occurred in all lakes during the early part of September.

4.2.1 Crooked Lake

Volunteer reports from a majority of the monitoring period indicated relatively stable conditions throughout the summer. Volunteers observed no gaps in the exclosure and reported that plants were healthy during all weeks. During the week of July 1, some of the wooden pallets became loose and moved within the plot. The volunteer re-set these pallets and placed concrete blocks on top of them to keep them in place. No further movement of the pallets was observed throughout the remainder of the summer. During the same site visit, the volunteer also added two more buoys and placed warning tape around the exclosure to increase visibility and decrease boating access in the area of the structure. Monitoring did not occur during much of September due to the lake closure from storms as Crooked Lake was closed to motorized boat traffic this time frame.

4.2.2 Chapman Lake

The first weekly report (July 10, 2007) on Chapman Lake indicated poor growth in the wooden pallets. The wooden pallets moved and some were observed on top of each other. JFNew filled the pallets with new substrate and replanted the structures, replacing them in their original location in the treatment. Subsequent volunteer reports indicated generally healthy plants, though the August 27, 2007 report indicated poor growth in the coconut mat plot. The volunteer observed no gaps in the exclosure during all monitoring visits.

4.2.3 Lake Tippecanoe

Volunteer reports indicated steady conditions throughout the summer. No gaps in the exclosure were noted and plants were noted as healthy during all volunteer visits.

4.2.4 Lake Wawasee

Volunteer observations noted generally poor growth during much of the summer with few plants observed above the water. No gaps were noted in the exclosure during any of the volunteer visits. Secchi depth measurements generally increased over the monitoring period.

4.3 Maintenance Activities

During the July 10 and 12 monthly monitoring visits, signs were posted outside the exclosure at each lake. Each sign identified the plot as part of an experimental planting project and provided a contact name and preferred contact information for each lake volunteer. Figure 7 shows for an example of the sign posted.

Figure 7. Sign posted at each planting site.

4.3.1 Crooked Lake

During the week of July 1, the Crooked Lake volunteer noticed that some of the wooden pallets shifted. The pallets were reset and concrete blocks were placed on top of the pallets to prevent them from shifting again. The volunteer also added two buoys and placed warning tape around the exclosure to increase visibility. JFNew placed a descriptive sign on July 12 but the plots required no other maintenance.

4.3.2 Chapman Lake

Volunteer reports from July 10, 2007 indicated that the wooden pallets moved and that some were lying on top of each other. JFNew visited the site on July 10 during the monthly monitoring visit. Two of the wooden pallets were observed floating at the water surface. A third pallet moved more than a meter away from its initial position. All three pallets were devoid of soil. The pallets were reset in their initial positions, partially filled with soil from the lake bottom, and the plants replanted. During the July 10 visit, a descriptive sign was also placed outside the exclosure. JFNew returned to the site on July 12, 2007. At this time, the pallets had begun floating again. The pallets were dug into the lake bottom and filled with substrate from the lake bottom. Plants were again replanted. In subsequent visits to the plot, no signs of movement were observed.

4.3.3 Lake Tippecanoe

A descriptive sign was placed outside the exclosure on July 10. No other maintenance activities were required at the Lake Tippecanoe plot throughout 2007.

4.3.4 Lake Wawasee

A descriptive sign was placed outside the exclosure on July 10. On July 25, two of the four wooden pallets were observed floating within the exclosure. On July 27, JFNew visited the site. The floating pallets were replaced in their initial positions, filled with substrate from the lake bottom, and replanted. All pallets were also tied down to the lake bottom using 14" metal staples and twine.

5.0 MONITORING PROGRESS

5.1 Volunteer Water Quality Monitoring

5.1.1 Methodology

Volunteers monitored each site weekly during the growing season. Monitoring began two weeks after the initial planting and continued through the end of September or when the volunteer took their boat off of the lake. During the monitoring visits, the volunteers measured the Secchi depth at the deepest point of the lake. Data were submitted with weekly structure and plant monitoring information. A copy of the datasheet is contained within Appendix X.

5.1.2 Water Quality Monitoring Results

In Crooked Lake, Secchi depth measurements varied between eight and ten feet (2.4 to 3.0 m) throughout the summer. In Chapman Lake, Secchi depth measurements varied between 8.5 and 10.5 feet (2.5 and 3.2 m) throughout the summer. In Lake Tippecanoe, Secchi depth measurements were generally low compared to the other lakes, varying between 3 and 4.6 feet (0.9 to 1.4 m) during the summer and increasing to 7.9 feet (2.4 m) at the end of August. In Lake Wawasee, transparencies in early to mid-July measured near four feet (1.2 m) in Conklin Bay. In late July, transparencies increased in Lake Wawasee to between six and seven feet (1.8 to 2.1 m) in Conklin Bay with transparencies in late September measured at 18 feet (5.5 ft) in the main body of Lake Wawasee. Table 1 details monitoring dates and measured transparencies for each lake.

Table 1. Secchi disk transparencies measured in the treatment lakes by volunteers, Summer 2007.

Lake Wawasee		Lake Tippecanoe		Crooked Lake		Chapman Lake	
6/21/2007	5.5	6/19/2007	4.5	6/20/2007	9.5	6/18/2007	8.5
7/6/2007	4	7/6/2007	4.6	7/15/2007	8.6	7/16/2007	9.8
7/15/2007	4	7/9/2007	3	7/20/2007	10.1	7/31/2007	10.4
7/31/2007	7	7/18/2007	4.3	8/2/2007	8.1	8/6/2007	8.6
8/5/2007	6.5	8/31/2007	7.9				
8/19/2007	6						
9/9/2007	7						
9/23/2007	18						

5.2 Aquatic Plant Growth Monitoring

5.2.1 Methodology

JFNew monitored the survival and growth of the plants once during the growing season, on August 28, 2007 (Wawasee, Tippecanoe, and Chapman lakes) and August 29, 2007 (Crooked Lake). During this monitoring visit, a botanist and field technician visited the treatment areas within each lake. Monitoring was performed by using an underwater plant viewer, which was constructed from a plastic tub with clear Plexiglas installed on the bottom. The underwater plant viewer was nearly submerged in the water to provide the monitor a way to view submerged vegetation (Figure 8). For each treatment, expansion zone, and control plot within the treatment area, the number of observed live-rooted vascular plants was tallied by species and each individual plant length was measured using a meter stick. (A sample data sheet can be found in Appendix H.) Measurements were collected from the longest stem or branch on a plant, from the substrate surface to the stretched tip of the plant. Notes were also made regarding whether planted individuals were flowering, fruiting, or vegetative. Any vascular plant species not planted but rooted within the plots, expansion zones, and control were also identified, counted, and noted on the datasheet. Fragments of plants were observed floating (not attached to rooted material) in several plots. These species were noted, but not counted toward the total number of plants in a given plot. Note that algae (including *Chara* spp.) were not counted in this study. Due to growth pattern and difficulty with measurement of individual stems, percent coverage of *Chara* was estimated within each treatment or expansion zone. A control plot was established outside of the exclosure using a square meter grid. The control was permanently marked with a buoy, and the location was surveyed with a GPS unit. The control plot was monitored using the same protocol used within the exclosure. Water depth was noted at each sampled plot. Photographs were taken of treatment and control areas using an underwater camera.

Figure 8. Underwater plant viewer in use during monitoring of the treatment areas during 2007.

Some of the plants installed in the treatment areas have growth forms and reproductive strategies that make counting individuals difficult. For example, eel grass is "vigorously stoloniferous… with long, ribbon-like basal submersed leaves from a very short, erect crown" (Gleason and Cronquist, 1991). Eel grass also "spreads vegetatively through turions, rhizomes, and seeds" (NRCS, no date). Because of the stoloniferous or rhizomatous roots, short crowns, and vegetative reproduction, many shoots can arise from a single plant. Such a growth pattern suggests that this single plant actually appears to be several individual plants, or colonies, which can spread rapidly from a single plant. In addition, the shoots can grow very close together, forming almost a carpet of leaves. These characteristics, coupled with the fact that sampling is occurring in water that is 3 to 4 feet deep, make it difficult to count planted individuals. During the monitoring inspections, a single plant was counted when it appeared to be rooted in the substrate. Thus, the number of individuals of some species, such as eel grass, grassy pondweed, Illinois pondweed, and chairmaker's rush, may be inflated in the results. Regardless, these multi-stemmed individuals are providing cover and habitat, which is one of the goals of the restoration.

5.2.2 Overall Results by Lake

Hard-stem bulrush and eel grass were the planted species observed most frequently in the treatment plots (37 hard-stem bulrush plants observed; 32 eel grass plants observed). Conversely, common waterweed and water shield were observed the least (0 common waterweed plants observed; 1 water shield plant observed). Common waterweed prefers slow moving or calcium rich waters (NRCS, no date). While common waterweed is found in all of the lakes in this study, the areas in which this study is taking place have abundant wave action. It is possible that this caused poor survival of planted common waterweed. Water shield grows best in clear, quiet lakes (Swink and Wilhelm, 1995), and has been shown to be difficult to establish through planting (Chittendon, 1956). Water shield may also have other specific nutrient or habitat requirements that are not currently known. While most of the lakes are relatively clear, there is a lot of wave action in the study areas.

The most commonly observed plants vary slightly between lakes. In Crooked Lake, eel grass and hard-stem bulrush were most commonly observed. In Chapman Lake, hard-stem bulrush was most commonly observed. In Lake Tippecanoe, Illinois pondweed was most commonly observed, and no individuals of hard-stem bulrush were present. In Lake Wawasee, eel grass and hard-stem bulrush were most common.

Crooked Lake

Figure 9 shows survival and presence results of aquatic plants in sampled plots within Crooked Lake. As seen in the figure, 19% of the 36 planted individuals survived in the direct planting treatment, 8% of the 36 planted individuals survived in the erosion control mat treatment, 31% of the 36 planted individuals survived in the concrete donut treatment, and 25% (plus additional individuals of eel grass) of the 36 planted individuals survived in the wooden pallet treatment. Five of the nine planted species were observed in the concrete donut planting medium, and survival of individuals of these five species was overall better than 50%. Only two of the planted species were represented by live individuals in the erosion control mat treatment. One of these species was hard-stem bulrush, which was found in all four treatment types, and had a survival rate of at least 50% in three of the four treatments. Pickerel weed was present in three of the four treatment types. Eel grass flourished in the wooden pallet treatment. No rooted plants were present within the control plots inside or outside of the exclosure or within the expansion zones between treatment areas. In addition, none of the planted common waterweed, grassy pondweed, or chairmaker's rush survived in any of the treatment areas.

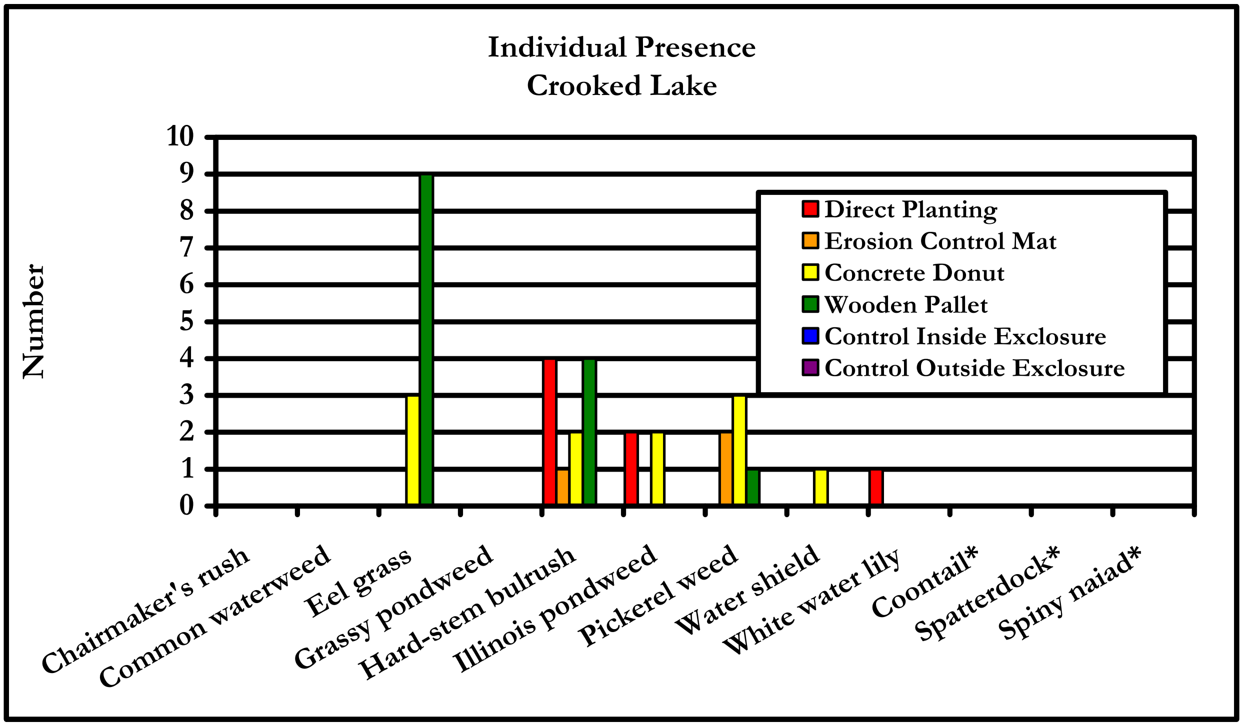

Figure 9. Plant presence in sampled plots within Crooked Lake. An asterisk (*) marks species that were not planted.

Chapman Lake

Figure 10 shows survival and presence results of aquatic plants in sampled plots within Chapman Lake. As displayed in the figure, 19% of the 36 planted individuals survived in the direct planting treatment, 8% of the 36 planted individuals survived in the erosion control mat treatment, 36% of the 36 planted individuals survived in the concrete donut treatment, and 28% (plus additional individuals of hard-stem bulrush) of the 36 planted individuals survived in the wooden pallet treatment. Six of the nine planted species were observed in the concrete donut planting medium. Survival of individuals of these five species was overall better than 50%. Five of the nine planted species were observed in the wooden pallet treatment, with hard-stem bulrush being the most prevalent species in this medium. Only one of the planted species, Chairmaker's rush, was represented by live individuals in the erosion control mat treatment. Hard-stem bulrush was observed in all four treatment types, with at least 50% survival of individuals in each treatment. Pickerel weed was present in three of the four treatment types. Muskgrass (*Chara* species) and spiny naiad (*Najas marina*) were observed in the control within the exclosure. Muskgrass covered 30% of the direct planting treatment and 90% of the control inside the exclosure. No plants were present within the expansion zones between treatment areas. In addition, none of the planted water shield, common waterweed, or grassy pondweed survived in any of the treatment areas.

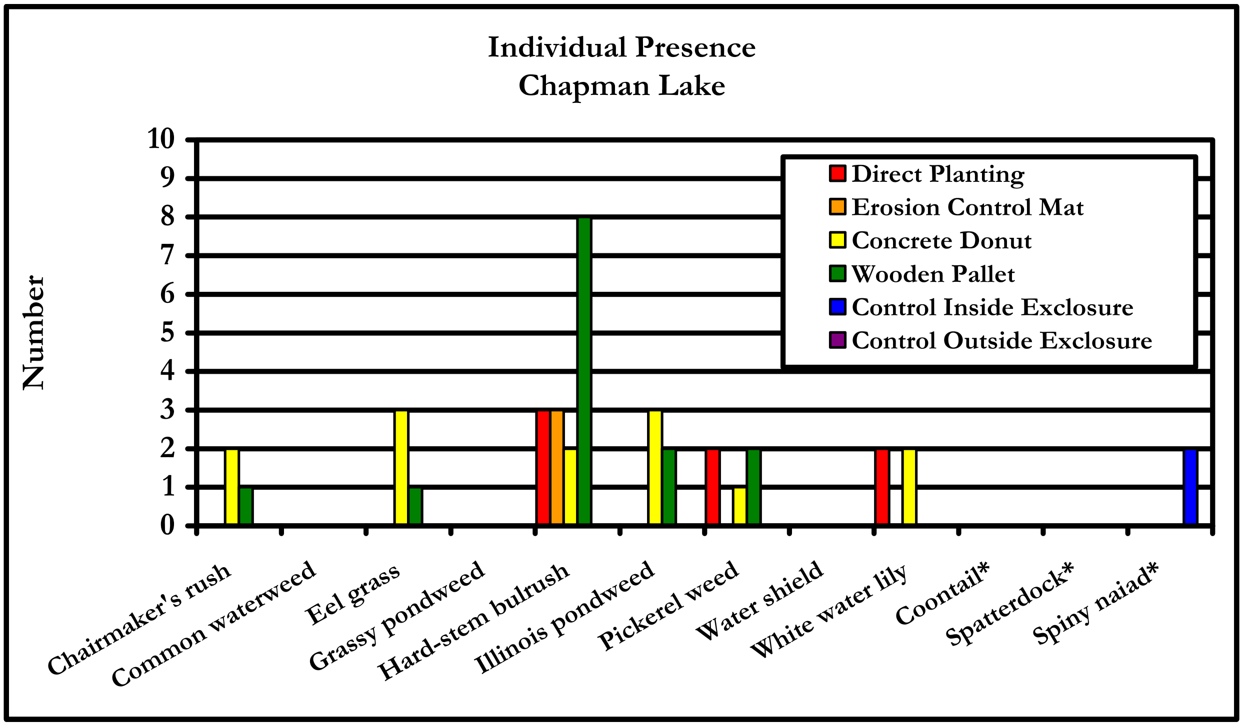

Figure 10. Plant presence in sampled plots within Chapman Lake. An asterisk (*) marks species that were not planted.

Lake Tippecanoe

Figure 11 shows survival and presence results of aquatic plants in sampled plots within Lake Tippecanoe. As seen in the figure, 17% (plus additional individuals of Illinois pondweed) of the 36 planted individuals survived in the direct planting treatment, 0% of the 36 planted individuals survived in the erosion control mat treatment, 11% of the 36 planted individuals survived in the concrete donut treatment, and 3% of the 36 planted individuals survived in the wooden pallet treatment. Two of the nine species were represented by living individuals in the direct planting and concrete donut treatment areas, and one species was represented by a single plant in the wooden pallet treatment. Pickerel weed and chairmaker's rush were present in the concrete treatment, eel grass and Illinois pondweed were present in the direct planting, and pickerel weed was present in the wooden pallet. None of the species survived in the erosion control mat treatment area. Coontail was observed in the control inside the exclosure; however, no plants were present within the control plots outside of the exclosure or within expansion zones between treatments. Illinois pondweed flourished in the direct planting treatment. None of the planted water shield, common waterweed, white water lily, grassy pondweed, or hard-stem bulrush survived in any of the treatment areas.

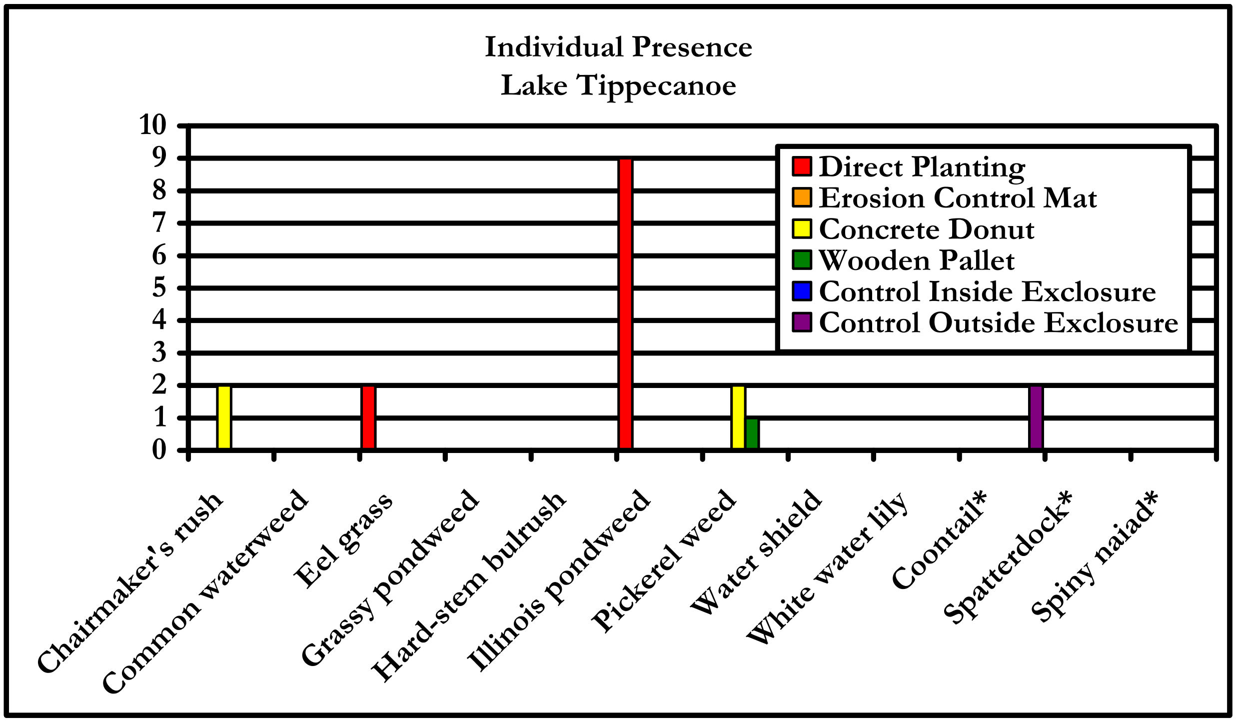

Figure 11. Plant presence in sampled plots within Lake Tippecanoe. An asterisk (*) marks species that were not planted.

Lake Wawasee

Figure 12 shows survival and presence results of aquatic plants in sampled plots within Lake Wawasee. As seen in the figure, 25% of the 36 planted individuals survived in the direct planting treatment, 14% of the 36 planted individuals survived in the erosion control mat treatment, 39% (plus additional individuals of eel grass) of the 36 planted individuals survived in the concrete donut treatment, and 22% (plus additional individuals of eel grass) of the 36 planted individuals survived in the wooden pallet treatment. Five of the nine planted species were observed in the direct planting and concrete donut treatments. Furthermore, survival of individuals of the five species present in the concrete donut treatment was overall better than 50%. Hard-stem bulrush was present in all four treatment types, and had a survival rate of 50% or better in each of the treatments. Grassy pondweed and eel grass were each observed in three of the four treatments, with eel grass flourishing in the concrete donut and wooden pallet treatments. Two volunteer spatterdock (*Nuphar advena*) plants were observed within the control plot outside of the exclosure. No plants were present within the control plots inside of the exclosure or within expansion zones between treatments. None of the planted water shield or common waterweed survived in any of the treatment areas.

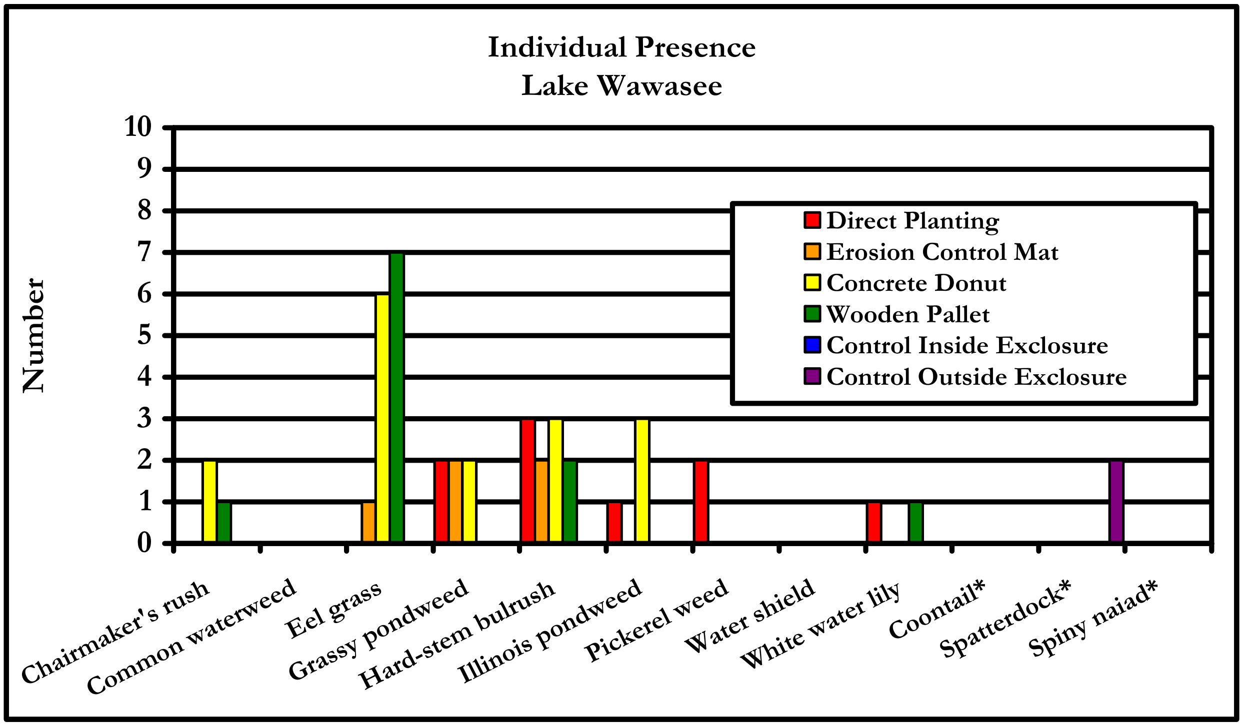

Figure 12. Plant presence in sampled plots within Lake Wawasee. An asterisk (*) marks species that were not planted.

5.2.3 Plant Presence by Treatment Type

Figure 13 displays the overall results of planting within each treatment type in each lake. Because there is no way to distinguish a volunteer from a planted individual, the results below show the total number of individuals of planted species (including volunteer individuals of planted species) found within each lake. As seen in the figure, the concrete donut and wooden pallet planting techniques were the most productive in terms of total number of individuals of planted species present, while the erosion control mat treatment showed the least plant survival.

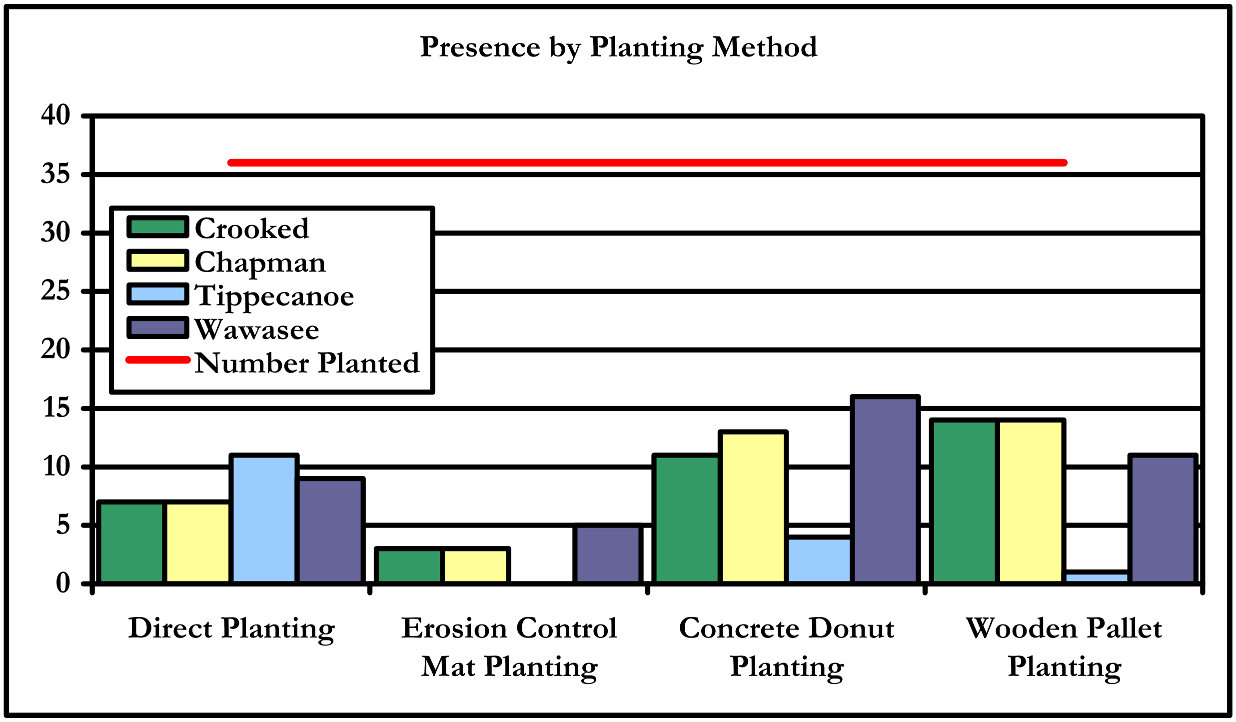

Figure 13. Total number of individuals of planted species in each lake, sorted by treatment type. The red line represents the total number of plants installed in each treatment type in each lake (36 plants).

Planted species were most abundant at Lake Wawasee and least abundant at Lake Tippecanoe. Results at Crooked and Chapman lakes were similar, and plant abundance was slightly less than that at Lake Wawasee. As seen in Figure X, survival of planted individuals during the first year was less than 50% in all treatment types in all lakes. Results shown for the direct planting treatment at Lake Tippecanoe are inflated due to the presence of nine individuals of Illinois pondweed when only four individuals were planted. Likewise, results shown for the concrete donut treatment at Lake Wawasee are inflated due to the presence of six individuals of eel grass when only four individuals were planted. Results shown for the wooden pallet treatment at Crooked Lake, Chapman Lake, and Lake Wawasee are inflated due to the presence of eight individuals of hard-stem bulrush at Chapman Lake, nine individuals of eel grass at Crooked Lake, and seven individuals of eel grass at Lake Wawasee, when only four individuals of each species were planted at each lake. This inflation represents either the presence of volunteer individuals or the spread of planted individuals.

5.2.4 Plant Height and Length by Lake

Crooked Lake

Figure 14 shows the average height of plants in the treatment and control areas at the time of planting (June 2007) versus at the time of sampling (August 29, 2007). As seen in the figure, species that were observed during the sampling inspection increased in size from the time that they were planted. This suggests in general that the structure has prohibited herbivory of planted species, showing that mortality was caused by some other source. At this time, the source of this mortality is unknown; however, possible issues include planting method issues, inability of the particular plant to survive in general within the conditions, or the condition of the species when planted. The latter could be the source of poor survival for white water lilies. As seen in the figure in Appendix E, planted white water lilies consisted of tubers with no stems at the time of planting. Hard-stem bulrush was the tallest plant observed, with individuals in the direct planting treatment averaging greater than 70 inches (177.8 cm) tall. Several species, including water shield (476%), white water lily (5000%), pickerel weed (975%), hard-stem bulrush (186%), and eel grass (1000%), showed impressive growth during the growing season.

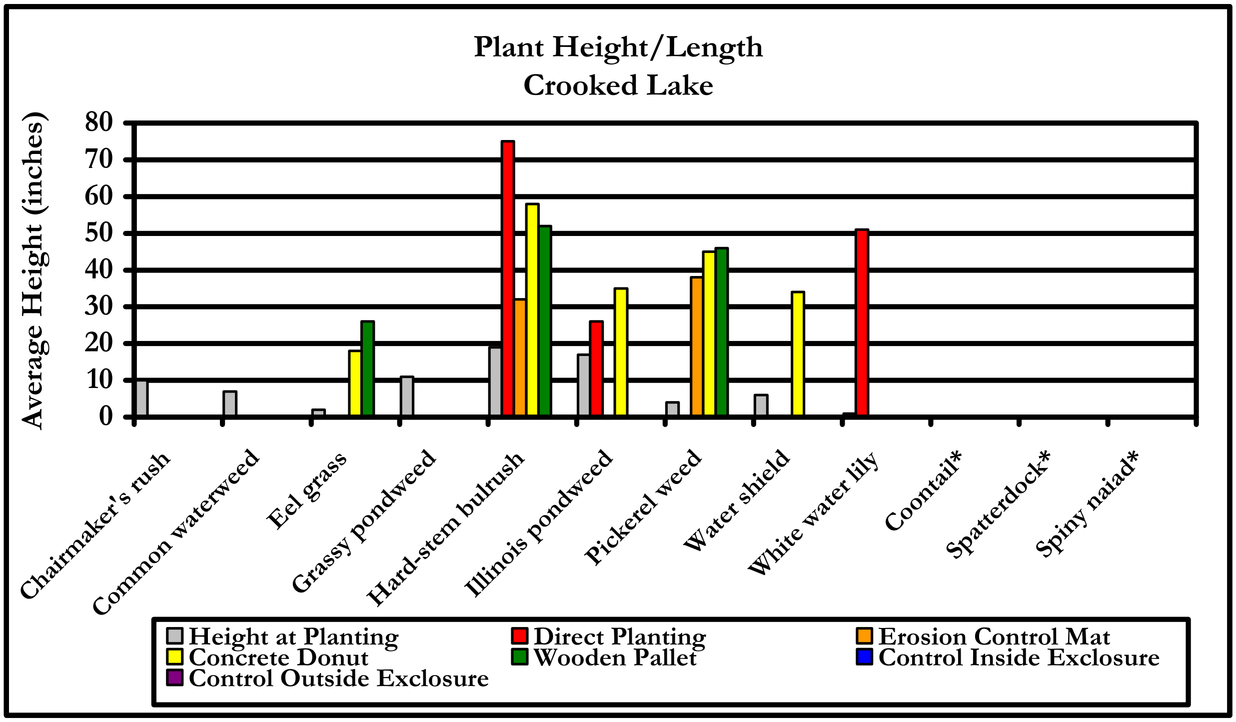

Figure 14. Comparison of average height of plants in Crooked Lake treatment and control areas at the time of planting versus at the time of sampling. An asterisk (*) marks species that were not planted.

Chapman Lake

Figure 15 shows the average height of plants in the treatment and control areas at the time of planting (June 2007) versus at the time of sampling (August 28, 2007). As seen in the figure, most of the species that were observed during the sampling inspection increased in size from the time that they were planted. This may indicate that, in general, the structure has prohibited herbivory of planted species, and that mortality has been caused by another source. Illinois pondweed in the wooden pallet treatment was shorter at the time of sampling than at the time of planting, and chairmaker's rush was the same height at the time of planting and sampling in the wooden pallet treatment. Hard-stem bulrush was the tallest plant observed, with individuals in the concrete donut and direct planting treatments averaging greater than 50 inches tall. Several species, including white water lily (3000%), pickerel weed (625%), hard-stem bulrush (145%), and eel grass (550%), showed impressive growth during the growing season.

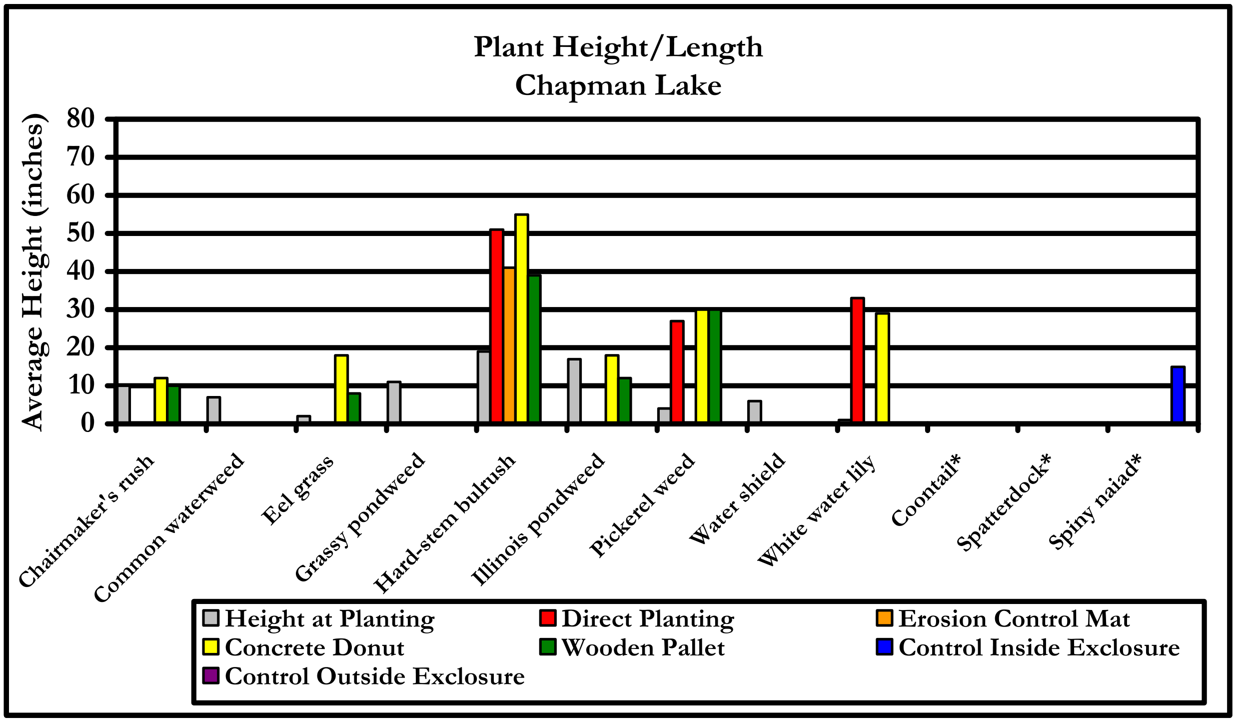

Figure 15. Comparison of average height of plants in Chapman Lake treatment and control areas at the time of planting versus at the time of sampling. An asterisk (*) marks species that were not planted.

Lake Tippecanoe

Figure 16 shows the average height of plants in the treatment and control areas at the time of planting (June 2007) versus at the time of sampling (August 28, 2007). As seen in the figure, species that were observed during the sampling inspection increased in size from the time that they were planted. This may indicate that in general, the structure has prohibited herbivory of planted species, and that mortality has been caused by another source. Pickerel weed was the tallest plant observed, with individuals in the concrete donut and wooden pallet treatments averaging greater than 35 inches (88.9 cm) tall. Pickerel weed (900%), hard-stem bulrush (130%), and eel grass (1650%) showed impressive growth during the growing season.

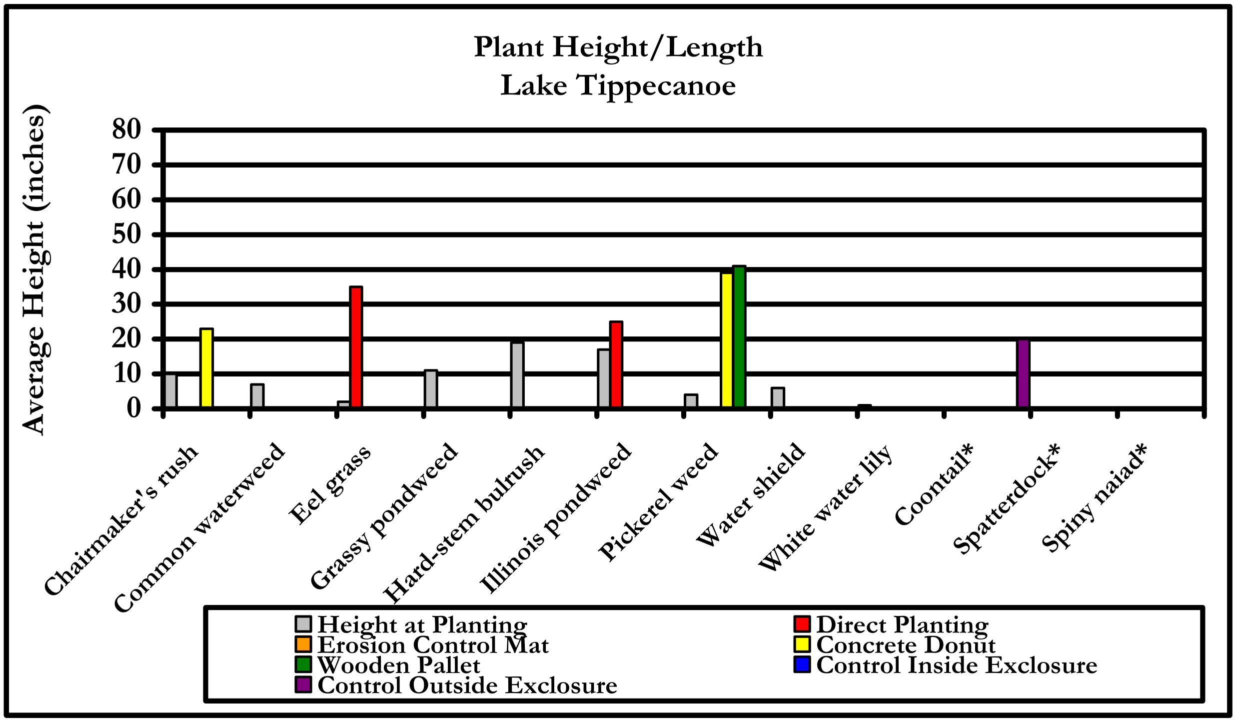

Figure 16. Comparison of average height of plants in Lake Tippecanoe treatment and control areas at the time of planting versus at the time of sampling. An asterisk (*) marks species that were not planted.

Lake Wawasee

Figure 17 shows the average height of plants in the treatment and control areas at the time of planting (June 2007) versus at the time of sampling (August 28, 2007). As seen in the figure, most of the species that were observed during the sampling inspection increased in size from the time that they were planted. This may indicate that in general, the structure has prohibited herbivory of planted species. Grassy pondweed in the direct planting treatment was shorter at the time of sampling than at the time of planting, while it was the same height at the time of planting and sampling in the concrete donut treatment. Pickerel weed was the tallest plant observed, with individuals in the direct planting treatment averaging greater than 40 inches (101.6 cm) tall. Several species, including white water lily (3000%), pickerel weed (2050%), grassy pondweed (425%), and eel grass (633%), showed increased growth during the growing season.

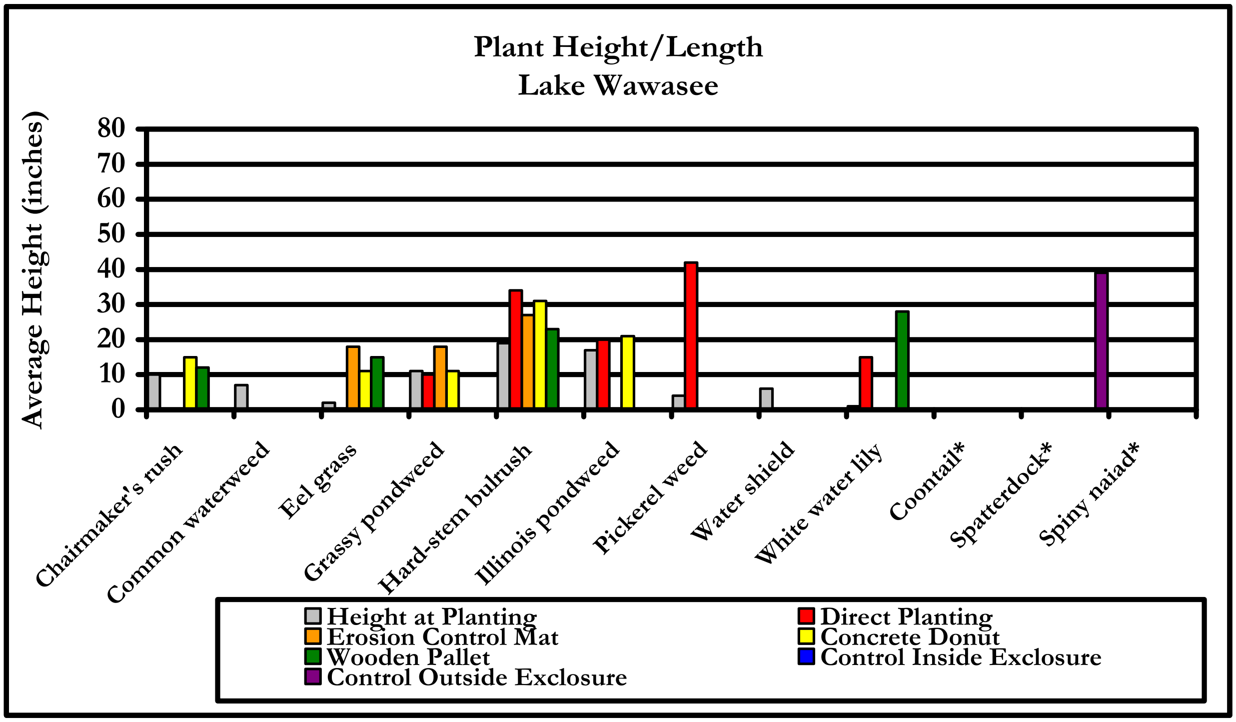

Figure 17. Comparison of average height of plants in Lake Wawasee treatment and control areas at the time of planting versus at the time of sampling. An asterisk (*) marks species that were not planted.

5.2.5 Flowering and Fruiting of Plant Species

Figure 18 displays a summary of results showing which species were observed to be flowering and/or fruiting at the time of the 2007 sampling. As seen in the figure, representatives from four of the nine planted species were flowering at the time of sampling. Eel grass was the most common plant found with reproductive structures, found with flowers in three of the four lakes. Pickerel weed was found with inflorescences in two of the lakes, while hard-stem bulrush and Illinois pondweed were each found with fruit in one of the lakes. In addition to being in flower in the most lakes, eel grass had more plants with inflorescences than the other flowering/fruiting species. In Crooked Lake and Lake Wawasee, more individuals of eel grass were found than what was planted, so some of the flowering individuals could have been volunteers or results of planted species spreading.

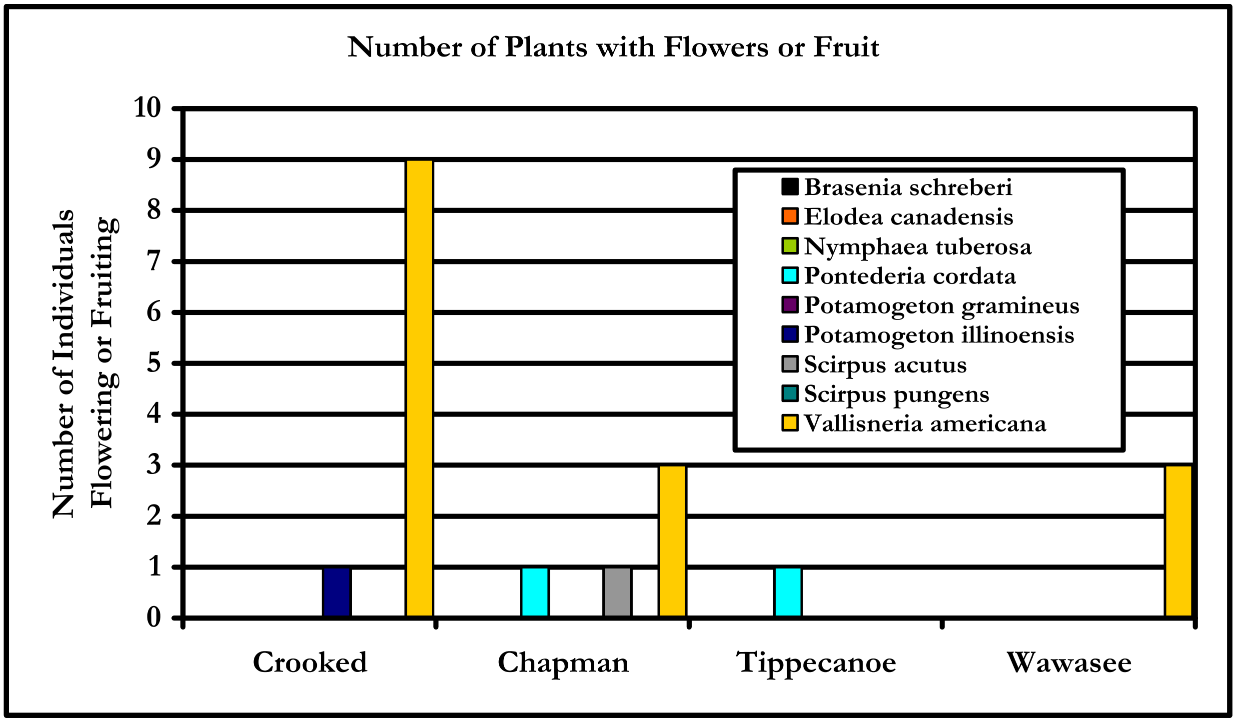

Figure 18. Number of individuals with flowers or fruit in each of the lakes.

5.2.6 Aquatic Plant Restoration Discussion

Although total survival of planted individuals was less than 50% in all lakes, results at Crooked Lake, Chapman Lake, and Lake Wawasee were encouraging. The poorer performance of planted species at Lake Tippecanoe was expected. Substrates in the planted areas at Crooked Lake, Chapman Lake, and Lake Wawasee are primarily loam, sand, and marl, while substrate in Lake Tippecanoe is primarily muck and sand. The muck and sand substrate made planting more difficult and also led to more turbidity throughout the year (likely leading to poorer plant survival) and during the sampling event (leading to more difficulty in finding vegetation that was present). Additionally, the density of filamentous algae within the Lake Tippecanoe planting site may have out-competed aquatic plants within this treatment. The survival percentage within each of the lakes was decreased by species that did not have any living representatives in a given lake or were generally unsuited to the planting conditions. However, some species flourished due to vegetative reproduction or plant habit and rooting structure.

Water shield was present only in the concrete donut treatment in Crooked Lake. Of the lakes in this study, water shield occurs naturally only in Crooked Lake. It has been shown to be difficult to establish by planting, and it occurs only in clear and quiet lakes. Because it is found naturally only in Crooked Lake, it is possible that there are other growth requirements that are present in Crooked Lake that are not present in the other four lakes.

Common waterweed was not observed in any of the study areas within any of the lakes. This was somewhat surprising because common waterweed is a ubiquitous plant that exists in all of the lakes in this study. However, it has been shown that common waterweed prefers slow moving, calcium-rich water. The areas in which the plantings occurred have abundant wave action. Therefore, it is possible that no common waterweed was present due to this abundant wave action. Additionally, it may be possible that common waterweed simply does not transplant well.

White water lily was observed in three of the four lakes, but generally in low abundance. This is likely due in part to the fact that planted individuals of white water lily consisted only of tubers, with no stems or emergent growth present. It is likely that some of these tubers never sprouted stems. Others may have been planted too shallow or too deep, especially in Lake Tippecanoe, where the substrate is soft and almost gelatinous. Also, planting white water lily in shallow water at mitigation wetlands often does not result in many live individuals (personal observations)

Pickerel weed was observed in all four lakes, with the best survival in Crooked and Chapman lakes. Survival of planted individuals in Crooked and Chapman lakes was less than 50%. One possible reason for mortality of planted individuals is that the water levels in the planting areas are deeper than that in which pickerel weed commonly grows naturally. Pickerel weed normally grows close to the shore and in shallow water (IMLS, 2001), often if water no more than 12 inches deep (UFCEA, 1999).

Grassy pondweed was only observed in Lake Wawasee, where 50% of the planted individuals survived. Grassy pondweed was present in all treatments in Lake Wawasee except the wooden pallet treatment. It is possible that the fragile root system of this species did not hold up well to the abundant wave action in the study areas or that many of the plants were uprooted.

Illinois pondweed was present in all four lakes. In most cases, in treatments where it was present, survival was greater than 50%. Like grassy pondweed, it is possible that some of the plants were uprooted due to the fragile root system of this species. It is unknown why Illinois pondweed flourished in the direct planting treatment in Lake Tippecanoe.

Hard-stem bulrush had the greatest survival rates overall within the four treatments at the four lakes. It was found in all four treatments within all of the lakes except Lake Tippecanoe. Survival of individuals within Crooked Lake, Chapman Lake, and Lake Wawasee was generally 50% or greater. It is likely that this species did not survive in Lake Tippecanoe due to the substrate and high turbidity.

Chairmaker's rush was found in less than half of the treatment areas, and where present, survival was 50% or less. This species is often found in water less than 6 inches deep, though it can also survive in water that fluctuates to up to 18 inches deep (NRCS, 1997). It is likely that chairmaker's rush did not survive at a higher rate due to the depth of water in the study areas.

Eel grass had the second greatest survival rates, next to hard-stem bulrush. It was found in all four lakes, but only in a total of eight of the sixteen treatments. In the wooden pallet treatment in Crooked Lake and Lake Wawasee and in the concrete donut treatment in Lake Wawasee, greater than the planted number of individuals were observed. Also, eel grass was observed to be in flower in three of the four lakes, more than any other species in the study. Eel grass is known to have an unstable root system, which allows wave action to uproot seemingly stable individuals. This has likely led to mortality or removal of some of the individuals. Additionally, eel grass' growth pattern likely allows for the counting of more individual plants than are likely represented in the treatments.

6.0 YEAR I PROJECT SUMMARY

During Year 1 of the Littoral Zone Restoration Research Project, a number of tasks were completed to provide a knowledge base for in-lake installation efforts. These included a literature search of previously-completed in-lake planting projects, techniques, and evaluations of success; review of treatment lakes to determine appropriate treatment locations; investigation of historic plant community structures within the treatment lakes; and public interaction in the form of public meetings at each of the four lakes and information handouts created for each lake association. Additionally, research project installation occurred during the week of June 18, 2007 and weekly, quarterly, and annual monitoring occurred throughout the remainder of 2007.

Overall, survival of each plant species varied by treatment type within each of the four lakes. The concrete donut treatment type was the most productive in terms of survival of planted individuals, followed closely by the wooden pallet treatment. The direct planting treatment contained the third highest survival rates. The lowest survival rates were observed in plants installed using the erosion control mat treatment. It is possible that the erosion control mats were not securely installed in the substrate, leading to movement and folding of the mats, and the subsequent mortality of planted individuals. Data suggest that a more structurally sound medium for planting will result in better survival of planted individuals, especially where there is greater wave action. In general, plant height and length increased from the time of planting to the time of sampling. Some species showed impressive growth (130 to 5000% increase in height) during the growing season. The fact that the height/length was greater during the sampling inspection than at the time of planting shows that the structures are likely reducing herbivory, and that mortality is likely due to another cause.

7.0 LITERATURE CITED

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APPENDIX A:

ANNOTATED BIBLIOGRAPHY OF AQUATIC PLANT RESTORATION

LITTORAL ZONE RESTORATION RESEARCH PROJECT 2007-2009

CROOKED, CHAPMAN, TIPPECANOE, AND WAWASEE LAKES

STEUBEN AND KOSCIUSKO COUNTIES, INDIANA

ANNOTED BIBLIOGRAPHY

Growth Limitations/Factors to Consider

Barko, J.W., M.S. Adams, and N.L. Clesceri. 1986. Environmental factors and their consideration in the management of submersed aquatic vegetation: A review. Journal of Aquatic Plant Management. 24: 1-10.

> The paper summarizes the findings of a workshop in New York on submersed macrophytes. The authors list a variety of parameters affecting aquatic vegetation (light, temperature, nutrients, sediment, and inorganic carbon) and discuss how and to what extent each can affect aquatic vegetation growth. Generally, light and sediment were agreed to have the largest effects on growth, with carbon limiting growth in some lakes. Both light and sediment have direct effects but the actual reaction on plants depends on the species and other factors. Nutrients were discussed as being limiting only very rarely.

Barko, J.W. and R.M. Smart. 1986. Sediment-related mechanisms of growth limitation in submersed macrophytes. Ecology 67(5): 1328-1340.

> A research paper studying the effects of sediment size and nutrient availability to growth of submergent plants. The study found that sandy sediments and sediments with high organic matter contents (mucks) had the lowest growth rates and aquatic plants grew best on medium-grain sized sediment.

Blindow, I. 1992. Long- and short-term dynamics of submerged macrophytes in two shallow eutrophic lakes. Freshwater Biology 28: 15-27.

> This study presents the results of a study of areal coverage of vegetation in two lakes over a eight-year period. Light availability and water levels played the largest roles in determining general patterns of vegetation coverage. Specifically, large drawdowns and flooding events greatly reduced overall coverage. Smaller fluctuations had different effects on different species or types of vegetation depending on how much of a fluctuation occurred and at what time of the year it occurred. Community composition within the coverage fluctuated and seemed to depend on inter-species competition.

Budelsky, R.A., and S.M. Galatowitsch. 2000. Effects of water regime and competition on the establishment of a native sedge in restored wetlands. Journal of Applied Ecology. 37(6): 971-985.

> The authors studied restoration of sedges in prairie pothole basins following restoration of hydrology. The researchers found that establishment during the first year after planting was the most critical component of the revegetation but that competition from invasives needed to be taken into account as well. It should be noted that many of their recommendations require the ability to adjust water levels manually. The same principles can be applied, however, to site selection.

Chambers, P.A. and J. Kaliff. 1985. Depth distribution and biomass of submersed aquatic macrophyte communities in relation to Secchi depth. Canadian Journal of Fisheries and Aquatic Sciences. 42: 701-709.

> The authors attempted to develop a model to predict maximum growth depth for separate types of macrophytes. The authors were able to use light data to explain the depth distribution of various plant communities but found discrepancies in the amount of biomass production. The authors concluded that while light may determine where macrophytes can grow, other factors determine how productive they will be. Additionally, the many of the plants studied grew to the 10-20% light level, not as deep as the 1% light level, as is normally cited as the lower depth limit for macrophytes.

Cunningham, P. Personal Communication. February 15, 2007.

> JFNew biologists talked to Paul Cunningham, Fisheries Policy Ecologist for the Wisconsin Department of Natural Resources about his experience with littoral zone enhancements/rehabilitations. He is a skeptic of trying to revegetate submergent plants since, in his experience, they will re-establish themselves on their own when the lake conditions are conducive to their growth. He said emergent vegetation may need some replanting since it does not expand as readily as submergents.

Koch, E.W. 2001. Beyond light: Physical, geological, and geochemical parameters as possible submersed aquatic vegetation habitat requirements. Estuaries 24(1): 1-17.

> Koch summarizes the factors that can influence where submergent vegetation can establish itself. He cites wave action, sediment size and organic matter content, and nutrient availability as the key factors besides light that determine the distribution of submergents. Several technical equations are provided but are unnecessary if the general concepts are kept in mind.

Middelboe, A.and S. Markager. 1997. Depth limits and minimum light requirements of freshwater macrophytes. Freshwater Biology 37: 553-568.

> The authors examined data from 153 lakes to study the maximum colonization depth for several types of submergent vegetation. They found that transparency did not always explain how deep submergent vegetation would grow. In lower transparency lakes, submergents could compensate for turbidity by growing longer shoots, inhibiting the role of transparency. In medium and high transparency lakes, the minimum colonization depth was related to transparency. The type of vegetation also played a role in determining the colonization depth, with shallower minimum depths for plants with high biomass/surface area ratios.

Nienhuis, P.H., J.P. Bakker, A.P. Grootjans, R.D. Gulati, V.N. de Jonge. 2002. The state of the art of aquatic and semi-aquatic ecological restoration projects in the Netherlands. Hydrobiologia 478: 219-233.

A general article on ecological restoration. The authors present the basic guideline that impairing factors must be removed before restoration efforts can be successful. In lake ecosystems, the authors state that water quality must be improved to reduce the algal presence before vegetation can be established.

Riis, T. and B.J.F. Biggs. 2003. Hydrologic and hydraulic control of macrophyte establishment and performance in streams. Limnology and Oceanography 48(4): 1488-1497.

This study examined the effect of flooding and high-velocity currents on macrophytes in streams. The authors found that stable conditions (relatively few flood events) were necessary for plants to become established. Additionally, they found that sediment shifting, not stem breakage, was responsible for most of the mortality associated with flooding. While this study was performed in streams, these guidelines should be applied to lakes with wave action.

Weisner, S.E.B. 1987. The relation between wave exposure and distribution of emergent vegetation in a eutrophic lake. Freshwater Biology 18: 537-544.

The study examined how emergent plants expand in areas open to wave action and areas sheltered from waves. Vegetation in sheltered areas expanded into deeper zones slower than vegetation in exposed areas. The author examined biomass of *Phragmites australis* in both areas and found lower productivities in sheltered areas. He suggested that in sheltered areas, softer substrates may inhibit expansion.

Weisner, S.E.B. 1991. Within-lake patterns in depth penetration of emergent vegetation. Freshwater Biology 26: 133-142.

The author studied seven lakes in Sweden to determine the effect of wave exposure and substrate softness on the maximum depth of emergent vegetation. They expected to find an increase in maximum depth with increased wave exposure. The data supported their expectations but substrate softness was a better predictor of depth penetration. The authors concluded that anchoring to the substrate had a larger influence on vegetation than physical wave action.

<u>Modeling/Design Studies</u>

Ballard, Jr., J.R. 1999. Determining and Mapping the Probability of Aquatic Plant Colonization. U.S. Army Corps of Engineers, Aquatic Plant Control Research Program. Vol. A-99-2.

A report summarizing a study characterizing where aquatic plants would be likely to colonize a pool in the Upper Mississippi River based on light availability, substrate condition, and proximity to source material. For each criteria, the pool was mapped with areas of favorable and unfavorable conditions delineated. A multiple regression analysis was used to develop a final map providing areas where aquatic plants would be likely to colonize.

Cho, H.J. and M.A. Poirrier. A model to estimate potential submersed aquatic vegetation habitat based on studies in Lake Pontchartrain, Louisiana. Restoration Ecology. 13(4): 623-629.

The authors developed a model to determine potential restoration sites in the southeast coastal region. They collected data from nearby lakes on the shore slope, the maximum planting depth (based on light availability) and the minimum planting depth (based on water regime).

Chymko, N. (editor) Guideline for Wetland Establishment on Reclaimed Oil Sands Leases. Oil Sands Wetlands Working Group. Environment Alberta. ESD/LM/00-1 Pub No. T/517.

This paper gives recommendations for the revegetation of wetlands, primarily focusing on choosing the appropriate depth distributions for each species. It also addresses whether revegetation should be attempted since many created wetlands either revegetate without any planting or replace the planted vegetation with other species after a couple of years. The authors provide a list of guidelines on when planting is appropriate, such as: proximity to seed sources, hydrology, and vegetation type.

Hawes, I., T. Riis, D. Sutherland, M. Flanagan. 2003. Physical constraints to aquatic plant growth in New Zealand lakes. Journal of Aquatic Plant Management 41: 44-52.

The authors attempted to develop a model to explain vegetation growth in lakes using data from lakes throughout New Zealand. They separated factors into those that determined variation in vegetation growth between lakes (water level fluctuation, water clarity) and those that determined variation in growth within a lake (wave action, slope). The authors were able to develop models for both types of variation but only the model for between-lake variation had any predictive power.

Schluter, C.A., and W.F. Godwin. Lake Griffin Fish Habitat Suitability Study. Proceedings of the Twenty-Third Annual ESRI User Conference, San Diego, CA., 2003.

A GIS was used to determine where aquatic vegetation would be most likely to establish itself in Lake Griffin for fish habitat. The model considered light availability, disturbance, and sediment depth. Suitability was determined based on simple criteria: Whether sufficient light was available, whether there was no disturbance in the area more than 50% of the time, and there was no organic sediment in the area. Areas that met all three criteria were "ideal." Areas that met the light and disturbance requirements but had a foot or less of organic sediment were "potential." Areas that did not meet the light or disturbance criteria or had more than a foot of sediment were "not feasible."

<u>**Techniques for Restoration**</u>

Allen, H. 2001. Shoreline Erosion Control Plan. AllEnVironment Consulting, for Oklahoma Water Resources Board, Water Quality Programs Division.

> This plan gives recommendations for the control of erosion along the shoreline of a reservoir in Oklahoma. The author recommends a variety of planting techniques, including vegetation alone, vegetation with a biolog breaker, and planting through erosion control mats. He does not provide data on any of the techniques but says that they have had success with each technique and provides recommendations for areas for each technique to be used.

Allen, H.A. and C.V. Klimas. 1986. Reservoir Shoreline Revegetation Guidelines. Technical Report E-86-13. U.S. Army Corps of Engineers, Waterways Experiment Station, Vicksburg, MS.

> This report provides a general overview of how to plan, implement, and maintain a shoreline revegetation project in a reservoir. When planning, the authors recommend considering the substrate quality and water level fluctuations when choosing plant species and timing. Compared to most other reports, they place a great deal more emphasis on water level fluctuations. They recommend using it to base decisions on what to plant, when to plant it, and what type of plantings to use (how long of a stem). They also provide some information on using erosion control mats and alternative erosion control measures to vegetate eroded sections of the shore.

Eubanks, C.E. and D. Meadows. 2002. A Soil Bioengineering Guide for Streambank and Lakeshore Stabilization. U.S. Department of Agriculture Forest Service, Technology and Development Program.

> This guide gives basic information on a variety of techniques for erosion control measures. It focuses on structural techniques but includes sections on using biologs as a breakwater for lakeshore plantings and using pre-vegetated erosion control mats.

Fischenich, C. 2001. Plant material selection and acquisition. U.S. Army Corp of Engineers, Engineer Research and Development Center Vicksburg, MS Environmental Lab. Ecosystem Management and Restoration Research Program. ERDC TN-EMRRP-SR-33.

> Fischenich gives general guidelines on choosing plants for riparian restoration projects. He recommends consulting a botanist familiar with the local vegetation and local areas that have been unaltered. Once a list of potential species is developed, the final selection should be made based on project goals and site-specific conditions.

Hellsten, S., J. Riihimaki, E. Alasaarela, R. Keranen. 1996. Experimental revegetation of the regulated lake Ontojarvi in northern Finland. Hydrobiologia 340: 339-343.

> The researchers studied vegetation efforts on a lake where water levels had been raised, causing erosion along the shoreline. Six vegetation designs were tested: soil fertilization using peat, soil protection using an oat cover crop, fertilization and oat cover crop together, willow bundles, erosion control matting, and a control. Survival rate of planted vegetation

was relative low, averaging 20% in the second year and the technique used made little difference.

Madsen, J. 1999. Point Intercept and Line Intercept Methods for Aquatic Plant Management. U.S. Army Corps of Engineers, Waterways Experiment Station. Aquatic Plant Control Technical Note MI-02.

Madsen presents two methods to quantify the extent of plant expansion within an area. In the point-intercept method, observers establish a grid of points within the area, travel to each point, and list the species present. In the line-intercept method, transects are established with presence/absence of each species documented at specific intervals.

Smart, R.M., G.O. Dick, and R.D. Doyle. 1998. Techniques for establishing native aquatic plants. Journal of Aquatic Plant Management. 36: 44-49.

This paper presents a general approach to vegetating lake and reservoir shorelines and provides a case study where the approach was used. The authors propose planting founder colonies of vegetation rather than large areas of plantings with protection against herbivory to ensure survival. Within a few years, the authors expect expansion of the colonies to fill in the rest of the lake. This approach was tested in Lake Conroe in Texas. Survival rates were high (greater than 90%) and by October of the second growing season, the colonies had expanded to a mean colony diameter of 2.5 m.

Smart, R.M. and G.O. Dick. 1999. Propagation and Establishment of Aquatic Plants: A Handbook for Ecosystem Restoration Projects. U.S. Army Corps of Engineers, Waterways Experiment Station. Technical Report A-99-4.

A general overview of restoration guidelines. The authors advise that site selection should be made based on light availability, protection from disturbance, and sediment texture. Species should be chosen based on what is native to the area and what will withstand the conditions in the lake. They recommend planting founder colonies prior to the growing season and implementing protective measures to prevent herbivory.
Management 34(6): 875-886.

<u>Case Studies</u>

Brouwer, E. and J.G.M. Roelofs. 2001. Degraded softwater lakes: Possibilities for restoration. Restoration Ecology. 9(2): 155-166.

The researchers studied 15 lakes in the Netherlands after restoration measures were implemented to improve water quality. Restoration measures typically involved removing sources of nutrients, adjustment of pH, and dredging of sediment. In all lakes, aquatic vegetation that had been historically present within the lake re-established within a few years after restoration.

Burdick, D., A. Mathieson, R. Grizzle, J. Adams, J. Greene, E. Hehre, H. Abeels, M. Brodeur. 2004. South Mill Pond: Assessment and Mapping of Ecological Communities to Support Restoration in Portsmouth, NH. Center for Marine Biology, Jackson Estuarine Laboratory.

South Mill Pond was the target of several restoration efforts, including elimination of combined sewer overflows, re-introduction of mussel species, and re-planting of salt marsh vegetation along the shores. Most planting sites did not establish themselves well, with coverages less than 10%. This likely occurred due to the continued presence of large amounts of algae in the pond.

Dick, G.O., R.M. Smart, and E.R. Gilliland. 2004. Aquatic Vegetation Restoration in Acadia Lake, Oklahoma: A Case Study. U.S. Army Corps of Engineers, Engineer Research and Development Center. ERDC/EL TR-04-7.

Dick, G.O., R.M. Smart, and J.K. Smith. 2004. Aquatic Vegetation Restoration in Cooper Lake, Texas: A Case Study. U.S. Army Corps of Engineers, Engineer Research and Development Center. ERDC/EL TR-04-5.

Dick, G.O. and R.M. Smart. 2004. Aquatic Vegetation Restoration in El Dorado Lake, Kansas: A Case Study. U.S. Army Corps of Engineers, Engineer Research and Development Center. ERDC/EL TR-04-6.

The US Army Corps of Engineers conducted three revegetation projects and documented the results. In all three cases, revegetation sites were chosen based on susceptibility to wave action, substrate quality, and light availability/shading. Species were chosen based on whether they were native to the area, whether they were invasive, and whether they could withstand the water level fluctuations of the lake. All planting areas were protected from herbivory by large-scale enclosures and small-scale fences, though the large-scale enclosures did not make a difference in survival rates. In general, the authors found sufficient growth and expansion after three years to call the projects a success, though only about half of the species planted successfully colonized each lake. One study included monitoring results five years after planting, two years after maintenance of exclusion fences ended. In that lake, many of the enclosures had been breached and vegetation had been eliminated from the area.

Eichler, L.W., R.T. Bombard, J.W. Sutherland, C.W. Boylen. 1995. Recolonization of the littoral zone by macrophytes following the removal of benthic barrier material. Journal of Aquatic Plant Management. 33: 51-54.

The authors studied the recolonization of lakes following the removal of bottom covers installed to remove Eurasian water milfoil. Recolonization occurred quickly within the lakes, with greater than 10 species growing at six of the seven sites. Percent cover was initially low but increased to between 20 and 40% the first year and approximately 60% the second year.

Jin, X., Q. Xu, and C. Yan. 2006. Restoration scheme for macrophytes in a hypertrophic water body, Wuli Lake, China. Lakes and Reservoirs: Research and Management 11: 21-27.

The authors propose a restoration program for Wuli Lake in China, which became impaired due to wastewater inputs from a nearby city. The authors examine the lake's water quality, sediment, and water regime. They propose improving the water quality while planting several submergent, emergent, estuarine, and wetland zones.

Kitchen, A. Monitoring Report for Wisconsin (1987-1999). U.S. Fish and Wildlife Service, Wisconsin Partners for Fish and Wildlife.

> Summary of results of monitoring from Partners for Fish and Wildlife program in Wisconsin. Overall, wetland restorations (which included littoral zone restorations, though a breakdown by percentages or number was not provided) were split relatively evenly between high, medium, and low vegetation quality, based on diversity and presence of invasive species. Sites in areas dominated by agriculture were more likely to fall in the low quality category while sites surrounded by other land uses were more likely to fall in the high quality category.

Kirschner, R. 2005. The Chicago Botanic Garden's lake enhancement program. Lakeline Summer 2005: 14-19.

> In 2000, the Chicago Botanic Garden began a program to restore six miles of shoreline along lakes within its boundaries. The program included both erosion control and revegetation efforts. In many of their plantings, the Garden used Geoweb, plastic webbing, and erosion control matting to protect the plants against erosion. The paper does not present any monitoring results but claims the program has been a success. Some practical considerations are also provided.

Larned, S.T., A.M. Suren, M. Flanagan, B.J.F. Biggs, T. Riis. 2006. Macrophytes in urban stream rehabilitation: Establishment, ecological effects, and public perception. 14(3): 429-440.

> The authors undertook a planting of three submerged species in a stream in New Zealand. 3,000 plants were installed and 90% survival was observed. Cover was estimated at greater than 50% in the second growing season.

Lauridsen, T.L., H. Sandsten, and P.H. Moller. 2003. The restoration of a shallow lake by introducing *Potamogeton spp.*: The impact of waterfowl grazing. Lakes and Reservoirs: Research and Management 8: 177-187.

> Water quality improvements had been made in a lake in Denmark but submerged vegetation did not re-establish itself. The authors undertook a series of enclosure studies to determine what factors were preventing growth. Plants within enclosures generally grew and expanded while unprotected plants were inhibited. Based on the size of holes in the enclosure material, the authors concluded that waterfowl had been the primary deterrent to vegetation establishment.

Nishihiro, J., M.A. Nishihiro, I. Washitani. 2006. Assessing the potential for recovery of lakeshore vegetation: Species richness of sediment propagule banks. Ecological Research. 21: 436-445.

> A vegetation restoration project was undertaken at a lake in Japan at constructed littoral areas. Sediment dredged from other areas of the lake was spread over the new littoral zones to supply a seed and propagule bank. Vegetation established itself at the sites within one month with 180 different species observed in the first year. Only one year of monitoring was performed, however, so it was not shown that these results were sustainable.

Sharitz, R.R., G.R. Wein, K.W. McLeod, A.D. Lowrance, J.H. Singer. L-Lake Shoreline Wetlands. University of Georgia Savannah River Ecology Laboratory. http://www.uga.edu/srel/ESSite/LLWetland_restoration.htm.

> L-Lake, a cooling reservoir was vegetated in 1987 to fulfill habitat requirements in the NPDES permit. Planted areas had greater percent cover and species richness than unplanted areas but areas were fairly similar after 10 years. Species survival was high for emergents (25 species survived out of 29 planted) but only two submergent species survived out of nine planted.

Undocumented Littoral Zone Restorations

Many communities have used littoral zone revegetations to improve habitat or aesthetics at local lakes and ponds. Most of these projects included simple design plans utilizing plantings along the lake shore with some wave protection (usually biologs) and did not include any post-planting monitoring. It is difficult to gauge how successful these projects have been, therefore, though most of the publicized projects have cited the project as a success. Below is a listing of websites describing various aquatic revegetation projects.

Newburgh Lake Restoration Plan –Michigan
http://www.rougeriver.com/techtop/newburgh/plan.html

Big Sandy Lake – Duluth, Minnesota
http://horticulture.coafes.umn.edu/vd/h5015/96papers/mcfadden.htm

Lake Conroe - Texas
http://www.texs.com/lcra/

Lake Phalen – St. Paul, Minnesota
http://www.stpaul.gov/depts/parks/environment/phalenrestoration.html

Little Fresh Lake - Massachusetts
http://www.cambridgema.gov/CWD/lfp_restoration.cfm

Smithville Lake, Missouri
http://www.mdc.mo.gov/conmag/2006/07/20.htm

University of Minnesota – Galatowitsch research study – Get in contact to discuss some options?
http://wrc.umn.edu/research/competitivegrants/2007galatowitsch.html

Silver Lake – Rochester, Minnesota
http://www.rochestermn.gov/departments/administration/pdf/geesesilverlakebufferfaqs.pdf

Lindenhurst Lakes – Illinois
http://www.lindenhurstil.org/lakescom/lake_management.htm

APPENDIX B:

HISTORIC AQUATIC PLANT SPECIES BY LAKE

LITTORAL ZONE RESTORATION RESEARCH PROJECT 2007-2009

CROOKED, CHAPMAN, TIPPECANOE, AND WAWASEE LAKES

STEUBEN AND KOSCIUSKO COUNTIES, INDIANA

Crooked Lake Aquatic Plant List

Abbreviation	Scientific Name	Common Name	Stratum	1967*	1973	1978*	2002*	2006*
BRASCH	*Brasenia schreberi*	Water shield	Emergent	X				X
CERDEM	*Ceratophyllum demersum*	Coontail	Submergent			X	X	X
CEPOCC	*Cephalanthus occidentalis*	Buttonbush	Emergent	X				X
CHARA	*Chara species*	Chara species	Submergent		X		X	X
DECVER	*Decodon verticillatus*	Whirled loosestrife	Emergent	X		X		
ELOCAN	*Elodea canadensis*	Common water weed	Submergent		X	X		X
ELONUT	*Elodea nuttallii*	Nuttall's water weed	Submergent					X
FILALG	*Filamentous algae*	Filamentous algae	Algae		X			
IRIPSE	*Iris pseudacorus*	Yellowflag iris	Emergent					X
IRIVIR	*Iris virginica*	Blue-flag iris	Emergent					X
JUNEFF	*Juncus effusus*	Soft rush	Emergent	X	X	X		
LEMMIN	*Lemna minor*	Common duckweed	Floating					X
LYTSAL	*Lythrum salicaria*	Purple loosestrife	Emergent					X
MYREXA	*Myriophyllum exalbescens*	Northern water milfoil	Submergent				X	
MYRHET	*Myriophyllum heterophyllum*	Various leaved watermilfoil	Submergent					X
MYRSPI	*Myriophyllum spicatum*	Eurasian watermilfoil	Submergent				X	X
MYRSP	*Myriophyllum* species	Milfoil	Submergent	X	X	X		
NAJFLE	*Najas flexilis*	Slender naiad	Submergent	X			X	X
NAJGRA	*Najas gracillima*	Brittle naiad	Submergent					X
NUPADV	*Nuphar advena*	Spatterdock	Floating	X	X	X		X
NUPVAR	*Nuphar variegatum*	Bullhead lily	Floating	X				
NYMTUB	*Nymphaea tuberosa*	White water lily	Floating	X	X	X	X	X
PONCOR	*Pontederia cordata*	Pickerel weed	Emergent	X	X	X		X
POTAMP	*Potamogeton amplifolius*	Large-leaf pondweed	Submergent					X
POTCRI	*Potamogeton crispus*	Curly leaf pondweed	Submergent		X	X	X	X
POTFOL	*Potamogeton foliosis*	Leafy pondweed	Submergent	X				X
POTGRA	*Potamogeton gramineus*	Grassy pondweed	Submergent				X	X
POTILL	*Potamogeton illinoensis*	Illinois pondweed	Submergent	X				X
POTNOD	*Potamogeton nodosus*	Long-leaf pondweed	Submergent	X				
POTPUS	*Potamogeton pusillus*	Small pondweed	Submergent	X	X			X
POTRIC	*Potamogeton richardsonii*	Clasping-leaf pondweed	Submergent				X	X
POTROB	*Potamogeton robbinsii*	Robbin's pondweed	Submergent	X				
POTZOS	*Potamogeton zosteriformis*	Flat-stem pondweed	Submergent		X		X	X
RANLON	*Ranunculus longirostris*	White water crowfoot	Submergent		X			X
SCIVAL	*Scirpus validus*	Softstem bulrush	Emergent					X
STUPEC	*Stuckenia pectinatus*	Sago pondweed	Submergent	X	X	X	X	X
TYPLAT	*Typha latifolia*	Broad leafed cattail	Emergent	X	X	X	X	X
UTRVUL	*Utricularia vulgaris*	Common bladderwort	Submergent	X	X	X	X	X
VALAME	*Valisneria americana*	Eel grass	Submergent	X	X			X
WOLCOL	*Wolffia columbiana*	watermeal	Floating					X
ZANPAL	*Zannichellia palustris*	Horned pondweed	Submergent					X
ZOSDUB	*Zosterella dubia*	Water stargrass	Submergent					X

*Plants were collected from all 3 basins.

Chapman Lake Aquatic Plant List

Abbreviation	Scientific Name	Common Name	Stratum	1964	1976	1991	1999	2000
CERDEM	*Ceratophyllum demersum*	Coontail	Submergent	X		X	X	X
CEPOCC	*Cephalanthus occidentalis*	Buttonbush	Emergent					X
CHARA	*Chara species*	Chara species	Submergent		X		X	X
COROBL	*Cornus obliqua*	Blue-fruited dogwood	Emergent					X
DECVER	*Decodon verticillatus*	Whirled loosestrife	Emergent	X				X
ELOCAN	*Elodea canadensis*	Common water weed	Submergent	X				
FILALG	*Filamentous algae*	Filamentous algae	Algae		X		X	X
HIBSP	*Hibiscus* sp.	Hibiscus	Emergent					X
IMPCAP	*Impatiens capensis*	Jewelweed	Emergent					X
JUNEFF	*Juncus effusus*	Soft rush	Emergent	X				
JUSAME	*Justicia americana*	water willow	Emergent					X
LEMNA sp.	*Lemna* species	Duckweed	Floating		X			X
MYRSPI	*Myriophyllum spicatum*	Eurasian watermilfoil	Submergent					X
MYRSP	*Myriophyllum* species	Milfoil	Submergent	X	X	X	X	
NAJFLE	*Najas flexilis*	Slender naiad	Submergent	X				X
NAJMIN	*Najas minor*	Brittle naiad	Submergent		X			
NAJSP	*Najas* species	Naiad species	Submergent				X	
NUPADV	*Nuphar advena*	Spatterdock	Floating	X	X	X	X	X
NUPVAR	*Nuphar variegatum*	Yellow pond lily	Floating	X				
NYMTUB	*Nymphaea tuberosa*	White water lily	Floating	X		X	X	X
PONCOR	*Pontederia cordata*	Pickerel weed	Emergent		X		X	X
POTAMP	*Potamogeton amplifolius*	Large-leaf pondweed	Submergent	X			X	
POTCRI	*Potamogeton crispus*	Curly leaf pondweed	Submergent	X		X	X	X
POTFOL	*Potamogeton foliosis*	Leafy pondweed	Submergent	X			X	
POTGRA	*Potamogeton gramineus*	Grassy pondweed	Submergent					X
POTILL	*Potamogeton illinoensis*	Illinois pondweed	Submergent					X
POTNAT	*Potamogeton natans*	Floating-leaf pondweed	Submergent	X				
SAGLAT	*Sagittaria latifolia*	Common arrowhead	Emergent		X			
SCISP	*Scirpus* species	Bulrush species	Emergent			X	X	X
SCIVAL	*Scirpus validus*	Softstem bulrush	Emergent		X			
STUPEC	*Stuckenia pectinatus*	Sago pondweed	Submergent	X	X	X		X
TYPSP	*Typha* species	Cattail species	Emergent		X	X	X	X
TYPLAT	*Typha latifolia*	Cattail	Emergent	X				
UTRVUL	*Utricularia vulgaris*	Common bladderwort	Submergent					X
VALAME	*Valisneria americana*	Eel grass	Submergent				X	X

Lake Tippecanoe Aquatic Plant List

Abbreviation	Scientific Name	Common Name	Stratum	1976*	1995*	2004	2005	2006
CERDEM	*Ceratophyllum demersum*	Coontail	Submergent	X	X	X	X	X
CHARA	*Chara species*	Chara species	Submergent		X	X	X	X
DECVER	*Decodon verticillatus*	Whirled loosestrife	Emergent	X	X	X	X	X
ELOCAN	*Elodea canadensis*	Common water weed	Submergent	X			X	X
FILALG	*Filamentous algae*	Filamentous algae	Algae		X			
HETDUB	*Heteranthera dubia*	Water star grass	Submergent	X		X	X	
LEMMIN	*Lemna minor*	Common duckweed	Floating	X				
LYTSAL	*Lythrum salicaria*	Purple loosestrife	Emergent	X	X	X	X	X
MYREXA	*Myriophyllum exalbescens*	Northern water milfoil	Submergent				X	X
MYRHET	*Myriophyllum heterophyllum*	Various leaved watermilfoil	Submergent					X
MYRSPI	*Myriophyllum spicatum*	Eurasian watermilfoil	Submergent			X	X	X
MYRSP	*Myriophyllum* species	Milfoil species	Submergent	X	X			
NAJFLE	*Najas flexilis*	Slender naiad	Submergent			X	X	X
NAJGUA	*Najas guadalupensis*	Southern naiad	Submergent				X	
NELLUT	*Nelumbo lutea*	American lotus	Floating	X	X	X	X	X
NUPADV	*Nuphar advena*	Spatterdock	Floating	X	X	X	X	X
NYMTUB	*Numphaea tuberosa*	White water lily	Floating	X	X	X	X	X
PELVIR	*Peltandra virginica*	Arrow arum	Emergent		X	X	X	X
PONCOR	*Pontederia cordata*	Pickerel weed	Emergent	X		X	X	X
POTAMP	*Potamogeton amplifolius*	Large-leaf pondweed	Submergent	X				X
POTCRI	*Potamogeton crispus*	Curly leaf pondweed	Submergent	X	X	X	X	X
POTGRA	*Potamogeton gramineus*	Grassy pondweed	Submergent			X		X
POTILL	*Potamogeton illinoensis*	Illinois pondweed	Submergent			X	X	X
POTPEC	*Potamogeton pectinatus*	Sago pondweed	Submergent	X	X	X	X	X
POTPUS	*Potamogeton pusillus*	Small pondweed	Submergent				X	
POTRIC	*Potamogeton richardsonii*	Richardson pondweed	Submergent			X	X	X
POTZOS	*Potamogeton zosteriformis*	Flat-stem pondweed	Submergent			X	X	X
SAGLAT	*Sagittaria latifolia*	Common arrowhead	Emergent	X				
SCISP	*Scirpus* species	Bulrush species	Emergent	X	X	X	X	X
TYPSP	*Typha* species	Cattail species	Emergent	X	X	X	X	X
VALAME	*Valisneria americana*	Eel grass	Submergent		X	X		X
WOLCOL	*Wolffia columbiana*	Watermeal	Floating	X				

*Plants were collected in lakes chain

Lake Wawasee Aquatic Plant List

Abbreviation	Scientific Name	Common Name	Stratum	1975	1985	2004	2005	2006
CEPOCC	*Cephalanthus occidentalis*	Buttonbush	Emergent			X		
CERDEM	*Ceratophyllum demersum*	Coontail	Submergent	X	X	X	X	X
CHARA	*Chara species*	Chara species	Submergent	X	X	X	X	X
DECVER	*Decodon verticillatus*	Whirled loosestrife	Emergent	X				
ELOCAN	*Elodea canadensis*	Common water weed	Submergent	X	X	X	X	X
FILALG	*Filamentous algae*	Filamentous algae	Algae	X	X	X		X
FONSP	*Fontinalis* species	water moss	Submergent					X
HIBSP	*Hibiscus palustris*	Swamp rose mallow	Emergent			X		X
HYPSP	*Hypnaceae* species	soft moss	Submergent					X
JUSAME	*Justicia americana*	Water willow	Emergent			X		X
LEMMIN	*Lemna minor*	Common duckweed	Floating				X	X
LEMTRI	*Lemna trisulca*	Star duckweed	Floating					X
LYTSAL	*Lythrum salicaria*	Purple loosestrife	Emergent	X	X			X
MYREXA	*Myriophyllum exalbescens*	Northern water milfoil	Submergent			X	X	X
MYRHET	*Myriophyllum heterophyllum*	Various leaved watermilfoil	Submergent			X	X	X
MYRSPI	*Myriophyllum spicatum*	Eurasian watermilfoil	Submergent			X	X	X
MYRSP	*Myriophyllum* species	Milfoil species	Submergent	X	X			
NAJFLE	*Najas flexilis*	Slender naiad	Submergent				X	X
NAJGUA	*Najas guadalupensis*	Southern naiad	Submergent				X	X
NAJMIN	*Najas minor*	Brittle naiad	Submergent				X	
NAJSP	*Najas* species	Naiad species	Submergent			X		
NIT sp.	*Nitella species*	Nitella species	Submergent			X	X	X
NUPADV	*Nuphar advena*	Spatterdock	Floating	X	X	X		
NUPVAR	*Nuphar variegatum*	Yellow pond lily	Floating					X
NYMTUB	*Numphaea tuberosa*	White water lily	Floating	X	X	X		X
PELVIR	*Peltandra virginica*	Arrow arum	Emergent	X	X	X		X
POLAMP	*Polygonum amphibium*	Water smartweed	Emergent	X	X			
PONCOR	*Pontederia cordata*	Pickerel weed	Emergent					X
POTAMP	*Potamogeton amplifolius*	Large-leaf pondweed	Submergent	X	X		X	
POTCRI	*Potamogeton crispus*	Curly leaf pondweed	Submergent	X	X	X	X	X
POTFOL	*Potamogeton foliosis*	Leafy pondweed	Submergent	X	X			X
POTGRA	*Potamogeton gramineus*	Grassy pondweed	Submergent			X	X	X
POTILL	*Potamogeton illinoensis*	Illinois pondweed	Submergent			X	X	X
POTNAT	*Potamogeton natans*	Floating-leaf pondweed	Submergent			X		X
POTNOD	*Potamogeton nodosus*	Long-leaf pondweed	Submergent				X	X
POTPEC	*Potamogeton pectinatus*	Sago pondweed	Submergent			X	X	X
POTPUS	*Potamogeton pusillus*	Small pondweed	Submergent			X		X
POTRIC	*Potamogeton richardsonii*	Richardson pondweed	Submergent			X	X	X
POTZOS	*Potamogeton zosteriformis*	Flat-stem pondweed	Submergent			X	X	X
SAGLAT	*Sagittaria latifolia*	Common arrowhead	Emergent	X	X		X	X
SCIACU	*Scirpus acutus*	Hard-stem bulrush	Emergent					X
SCISP	*Scirpus* species	Bulrush species	Emergent	X	X			
TYPANG	*Typha angustifolia*	Narrow leafed cattail	Emergent					X
TYPSP	*Typha* species	Cattail species	Emergent	X	X	X		

Abbreviation	Scientific Name	Common Name	Stratum	1975	1985	2004	2005	2006
UTRVUL	*Utricularia vulgaris*	Common bladderwort	Submergent			X	X	X
VALAME	*Valisneria americana*	Eel grass	Submergent			X	X	X
ZANPAL	*Zannichellia palustris*	Horned pondweed	Submergent				X	

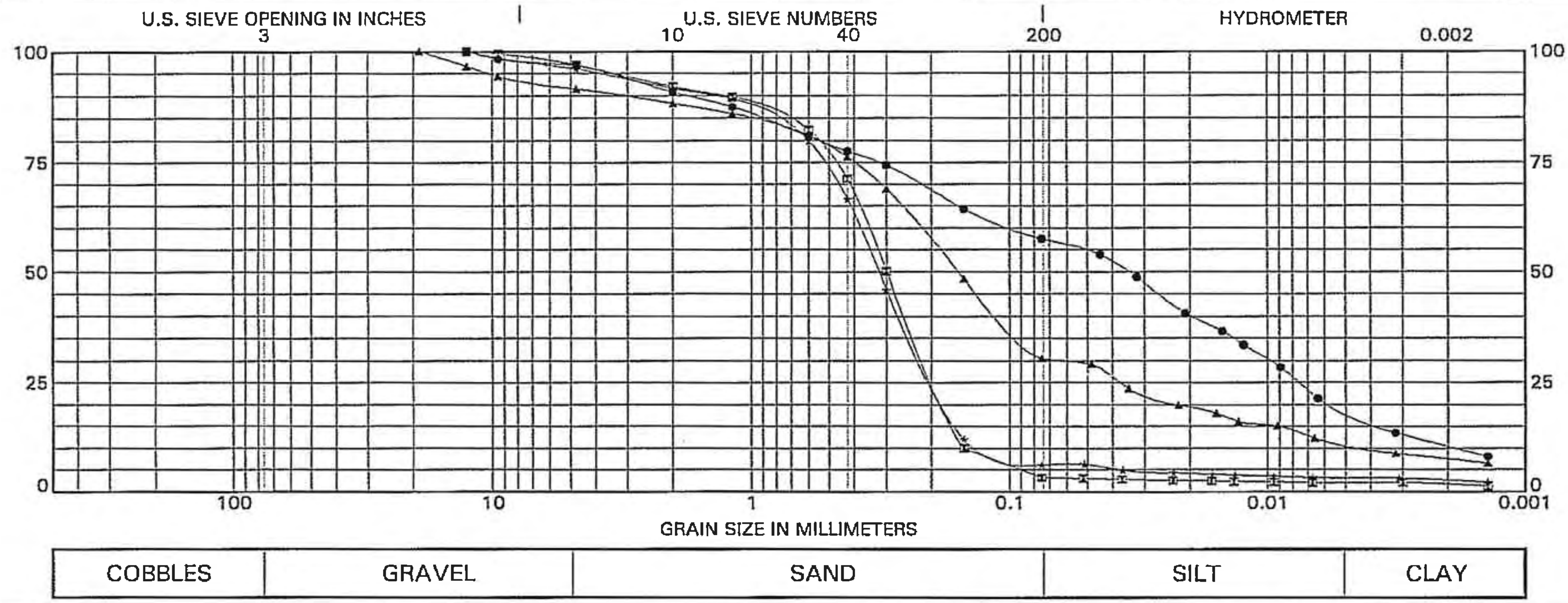
APPENDIX C:

LABORATORY SEDIMENT SAMPLING RESULTS

LITTORAL ZONE RESTORATION RESEARCH PROJECT 2007-2009

CROOKED, CHAPMAN, TIPPECANOE, AND WAWASEE LAKES

STEUBEN AND KOSCIUSKO COUNTIES, INDIANA



Boring No.	Sample No.	Depth, ft.	USCS Classification [1]	Atterberg Limits LL	PL	PI	% Gravel	% Sand	% Silt	% Clay	% Moisture [2]	Dry Density lbs/cu ft.	Permeability [3] cm/sec	Specific Gravity [4]	Porosity, %	Organic, % [5]
● CHA LAKE	1	0.0 - 0.0	CL, LEAN CLAY (visual)				3.3	39.2	38.9	18.6	—	—	—	—	—	6.70
⊠ CRO LAKE	1	0.0 - 0.0	SP, POORLY GRADED SAND				3.1	93.7	1.2	2.0	—	—	—	—	—	0.80
▲ TIP LAKE	1	0.0 - 0.0	SM, SILTY SAND (visual)				8.5	61.0	19.5	11.0	—	—	—	—	—	5.20
✶ WAW LAKE	1	0.0 - 0.0	SP-SM, POORLY GRADED SAND with SILT				4.0	89.9	3.0	3.1	—	—	—	—	—	7.70

EARTH EXPLORATION Inc.

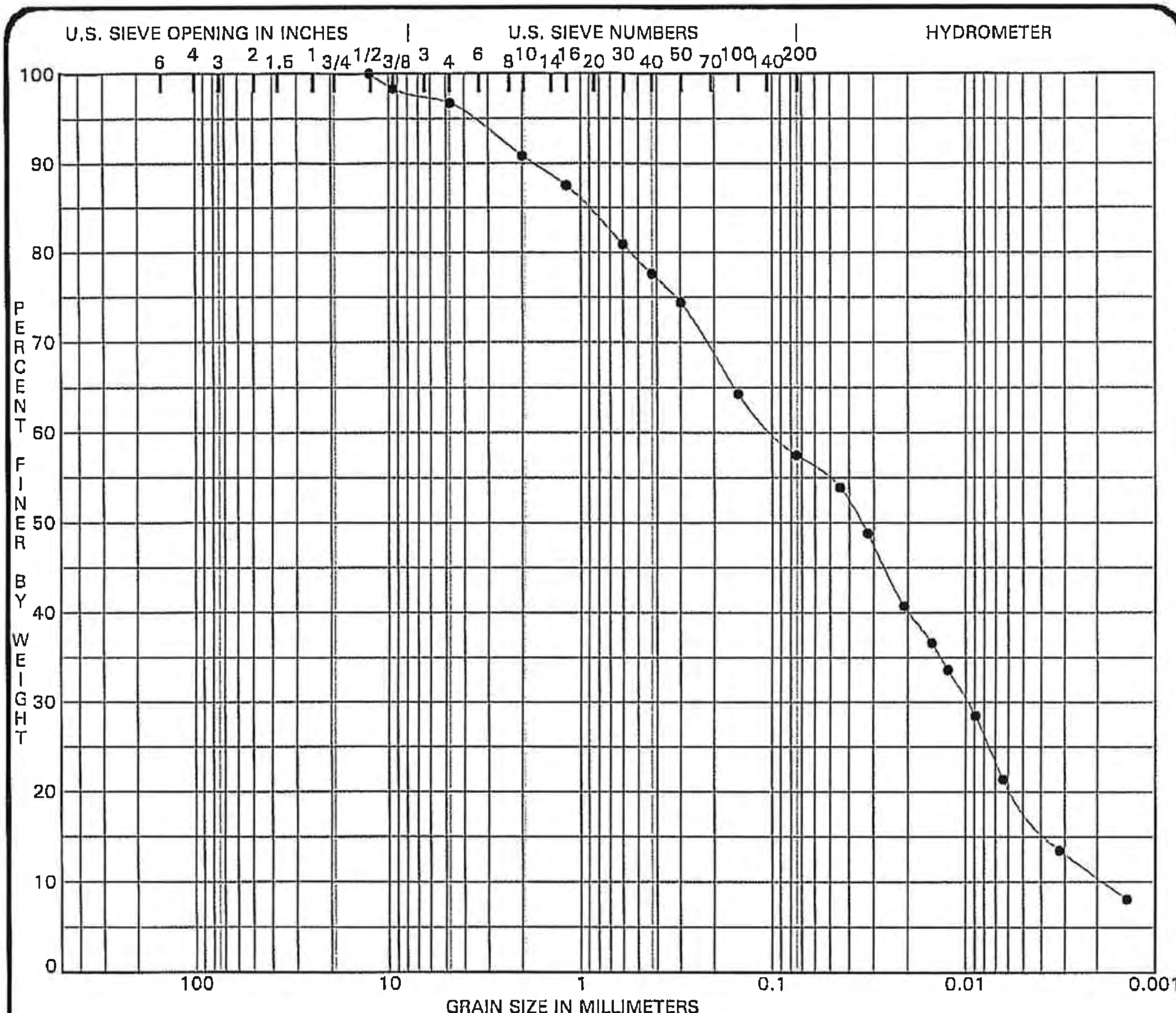
Client Project No.
Report Date 6-1-07
EEI Project No. 2-07-042

Project Sediment Analysis
Location Various Counties, Indiana
Client J.F. New & Associates, Inc.

SUMMARY OF LABORATORY TEST RESULTS

Earth Exploration, Inc.
7770 West New York Street Indianapolis, Indiana 46214
317-273-1690 / 317-273-2250 (Fax)

1 ASTM D 422 & D 2487
2 ASTM D 2216
3 ASTM D 5084/D 2434
4 ASTM D 854
5 ASTM D 2974



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

Sample Identification	USCS Classification	MC%	LL	PL	PI	Cc	Cu
● CHA LAKE 1 ---	CL, LEAN CLAY (visual)	---					

% Gravel (>4.75mm)	% Sand (4.75 to .075mm)	% Silt (.075 to .005 mm)	% Clay (<.005mm)
3.3	39.2	38.9	18.6

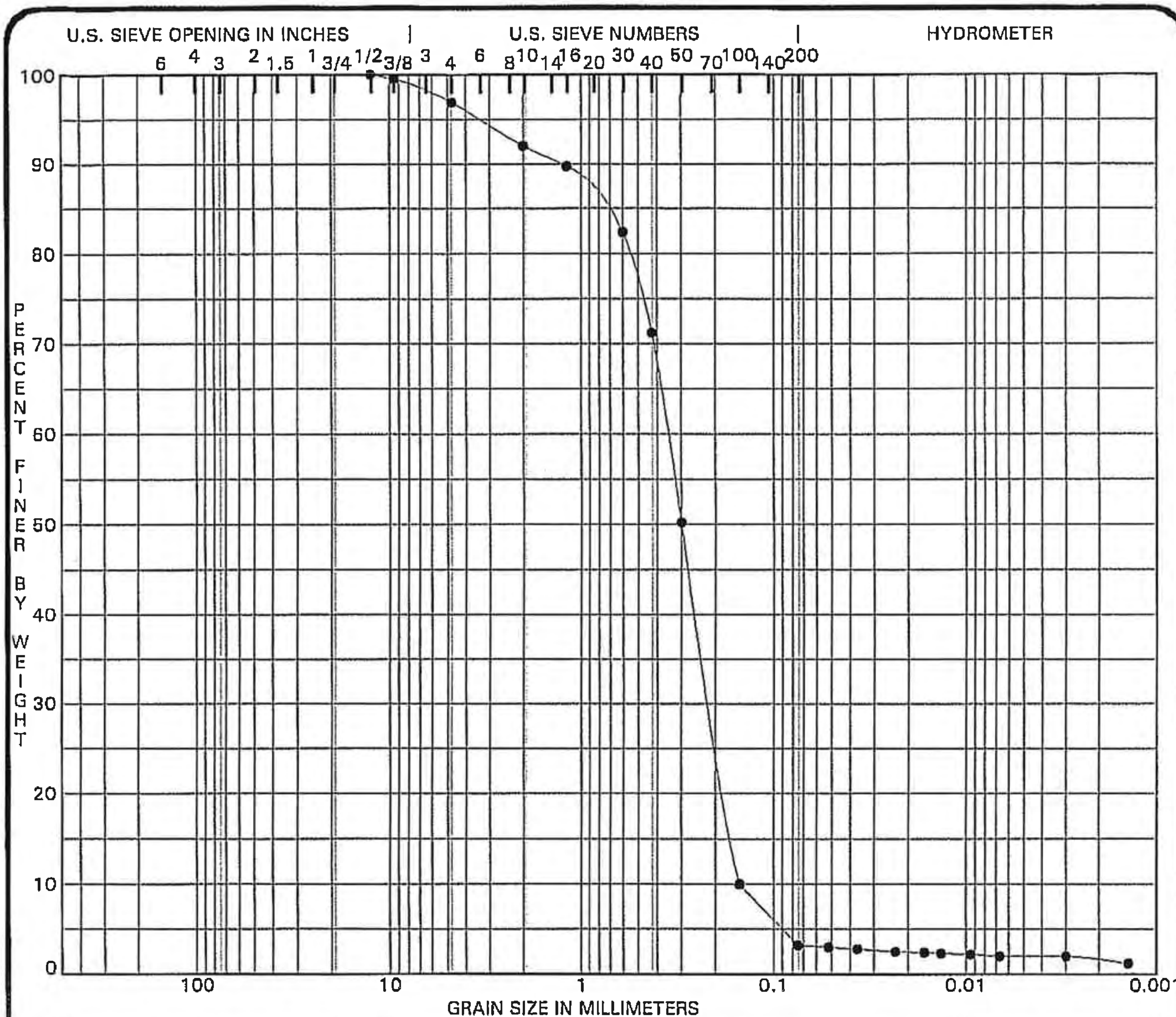
Grain Size (mm)	% Passing	Grain Size (mm)	% Passing	Grain Size (mm)	% Passing
64.0	100.0	0.5	79.2	0.016	37.4
16.0	100.0	0.25	71.7	0.008	26.2
4.0	95.5	0.125	62.5	0.005	18.6
2.0	90.8	0.075	57.5	0.002	10.4
1.0	85.9	0.050	54.7		

EARTH EXPLORATION, Inc.

PROJECT Sediment Analysis
LOCATION Various Counties, Indiana
CLIENT J.F. New & Associates, Inc. CLIENT ID NO.
EEI PROJECT NO. 2-07-042 DATE 6-1-07

GRAIN SIZE DISTRIBUTION CURVE

Earth Exploration, Inc.
7770 West New York Street Indianapolis, Indiana 46214
317-273-1690 / 317-273-2260 (Fax)



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

Sample Identification	USCS Classification	MC%	LL	PL	PI	Cc	Cu
● CRO LAKE 1 —	SP, POORLY GRADED SAND	---				0.85	2.4

% Gravel (>4.75mm)	% Sand (4.75 to .075mm)	% Silt (.075 to .005 mm)	% Clay (<.005mm)
3.1	93.7	1.2	2.0

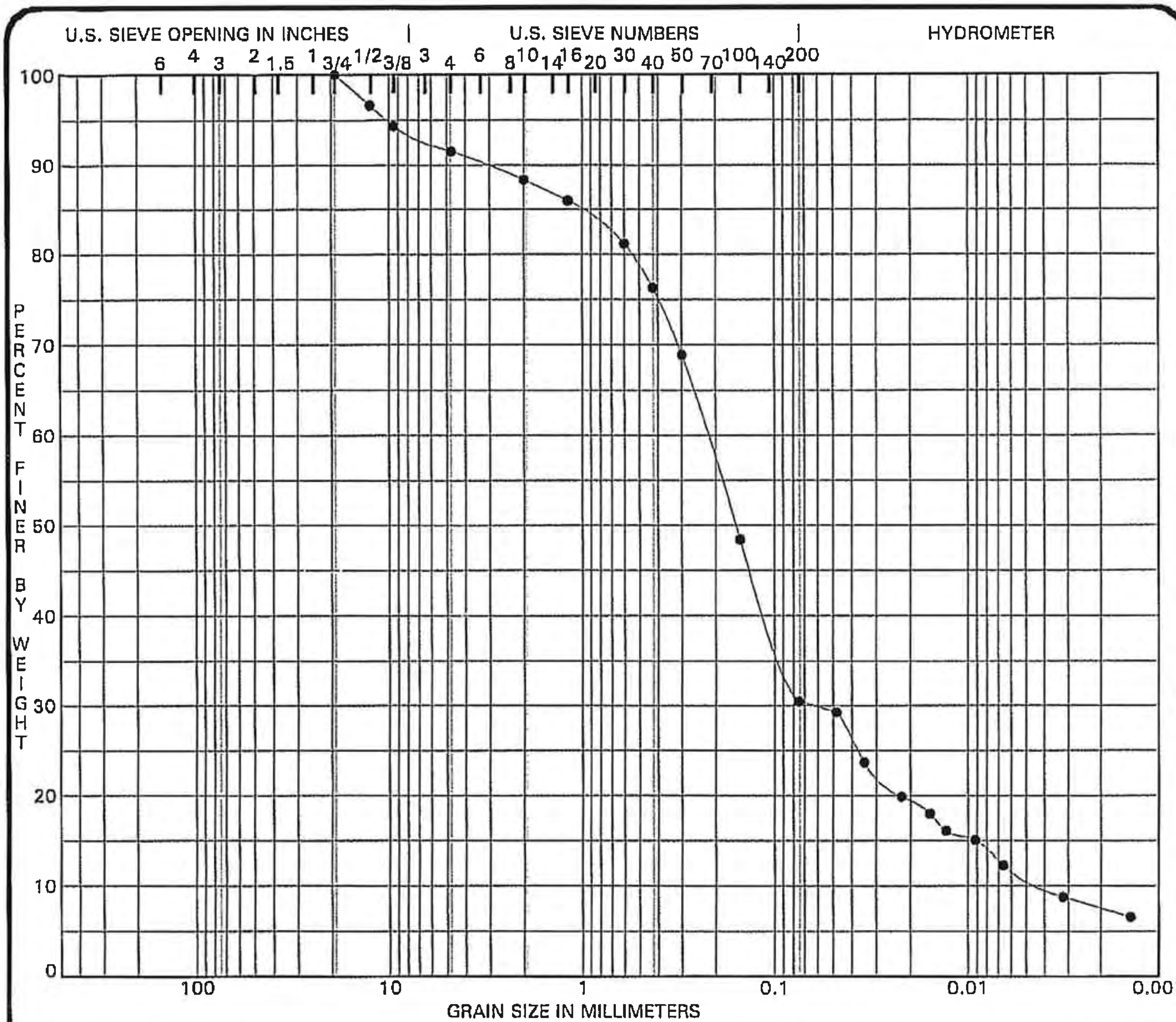
Grain Size (mm)	% Passing	Grain Size (mm)	% Passing	Grain Size (mm)	% Passing
64.0	100.0	0.5	76.5	0.016	2.4
16.0	100.0	0.25	39.6	0.008	2.1
4.0	95.9	0.125	8.2	0.005	2.0
2.0	92.0	0.075	3.2	0.002	1.6
1.0	87.9	0.050	3.0		

EARTH EXPLORATION Inc

PROJECT Sediment Analysis
LOCATION Various Counties, Indiana
CLIENT J.F. New & Associates, Inc. **CLIENT ID NO.**
EEI PROJECT NO. 2-07-042 **DATE** 6-1-07

GRAIN SIZE DISTRIBUTION CURVE

Earth Exploration, Inc.
7770 West New York Street Indianapolis, Indiana 46214
317-273-1690 / 317-273-2260 (Fax)



<table>
<tr><td rowspan="2">COBBLES</td><td colspan="2">GRAVEL</td><td colspan="3">SAND</td><td rowspan="2">SILT OR CLAY</td></tr>
<tr><td>coarse</td><td>fine</td><td>coarse</td><td>medium</td><td>fine</td></tr>
</table>

Sample Identification	USCS Classification	MC%	LL	PL	PI	Cc	Cu
● TIP LAKE 1 —	SM, SILTY SAND (visual)	---					

% Gravel (>4.75mm)	% Sand (4.75 to .075mm)	% Silt (.075 to .005 mm)	% Clay (<.005mm)
8.5	61.0	19.5	11.0

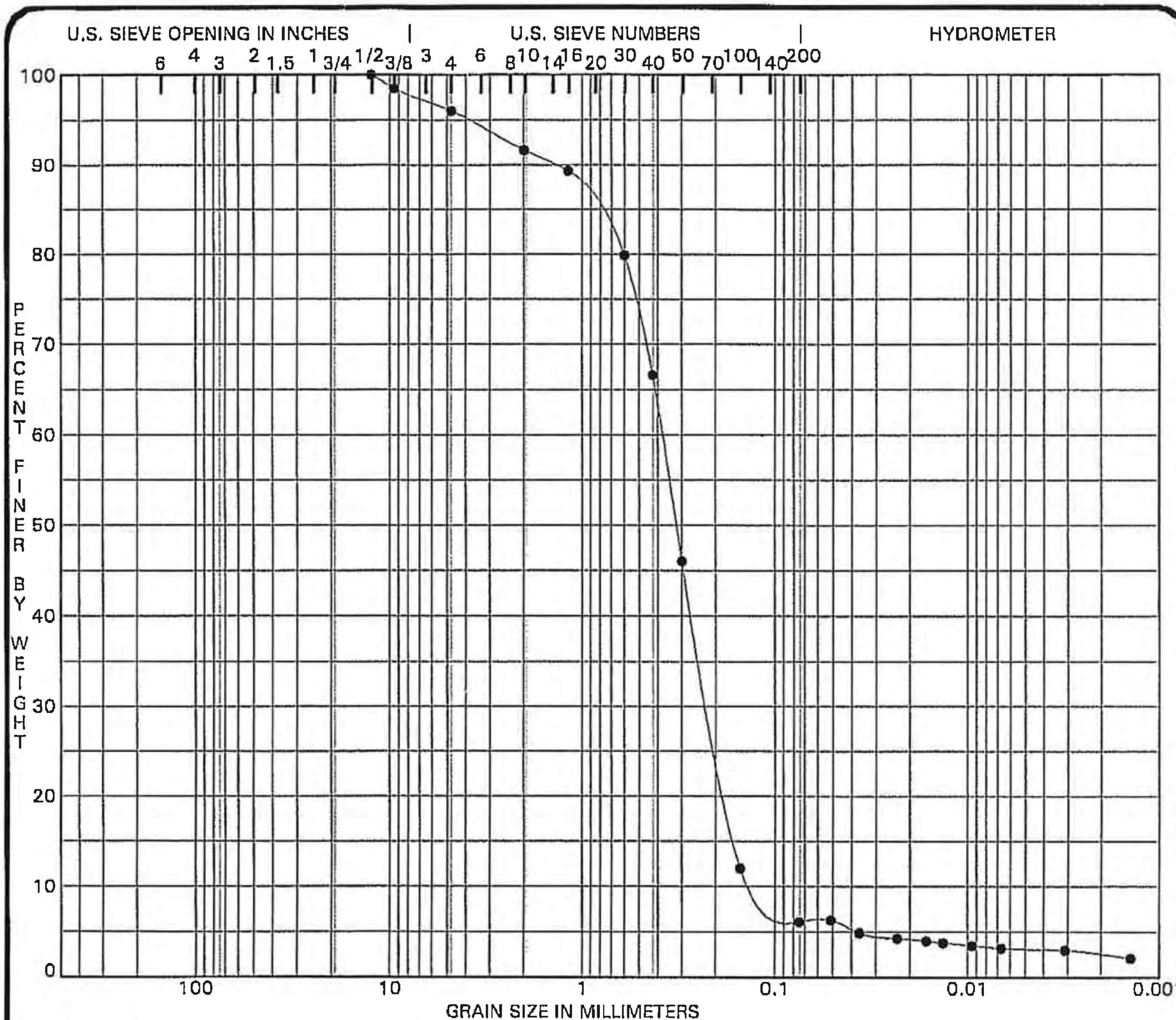
Grain Size (mm)	% Passing	Grain Size (mm)	% Passing	Grain Size (mm)	% Passing
64.0	100.0	0.5	78.6	0.016	18.1
16.0	98.6	0.25	63.5	0.008	13.9
4.0	90.9	0.125	43.7	0.005	11.0
2.0	88.3	0.075	30.5	0.002	7.5
1.0	84.8	0.050	29.4		

EARTH EXPLORATION Inc

PROJECT Sediment Analysis
LOCATION Various Counties, Indiana
CLIENT J.F. New & Associates, Inc. CLIENT ID NO.
EEI PROJECT NO. 2-07-042 DATE 6-1-07

GRAIN SIZE DISTRIBUTION CURVE

Earth Exploration, Inc.
7770 West New York Street Indianapolis, Indiana 46214
317-273-1690 / 317-273-2250 (Fax)



COBBLES	GRAVEL		SAND			SILT OR CLAY
	coarse	fine	coarse	medium	fine	

	Sample Identification	USCS Classification	MC%	LL	PL	PI	Cc	Cu
●	WAW LAKE 1 ---	SP-SM, POORLY GRADED SAND with SILT	---				1.04	3.2

% Gravel (>4.75mm)	% Sand (4.75 to .075mm)	% Silt (.075 to .005 mm)	% Clay (<.005mm)
4.0	89.9	3.0	3.1

Grain Size (mm)	% Passing	Grain Size (mm)	% Passing	Grain Size (mm)	% Passing
64.0	100.0	0.5	72.9	0.016	4.0
16.0	100.0	0.25	37.1	0.008	3.4
4.0	95.1	0.125	10.4	0.005	3.1
2.0	91.6	0.075	6.1	0.002	2.5
1.0	87.0	0.050	6.2		

EARTH EXPLORATION &

PROJECT Sediment Analysis
LOCATION Various Counties, Indiana
CLIENT J.F. New & Associates, Inc. CLIENT ID NO.
EEI PROJECT NO. 2-07-042 DATE 6-1-07

GRAIN SIZE DISTRIBUTION CURVE

Earth Exploration, Inc.
7770 West New York Street Indianapolis, Indiana 46214
317-273-1690 / 317-273-2250 (Fax)

eis

REPORT OF ANALYSIS

Mr. Aaron Johnson
J.F. New & Associates
708 Roosevelt Road
Walkerton, IN 46574
Tel No: 574-586-3400
Fax No: 574-586-3446
PO No:
Project Name: **Littoral Zone Restoration**

Report Date:	5/21/07
EIS Order No:	**070400171**
EIS Sample No:	115180
EIS Project No:	2325-1000-07
Client Sample ID:	**Chapman**
Date Collected:	4/18/07
Date Received:	4/20/07
Collected By:	A. Johnson

This report presents results of analysis for your sample(s) received under our Order No above. This Number is to be used in all inquiries concerning this report. The EIS Sample No above, as well as your Sample ID, refer to the first sample in a multi-sample submission

DEFINITIONS:

RDL = Reporting Detection Limit for your sample and may include adjustments for matrix interferences.
nd = Not Detected at the RDL value. If present, result is less than this value.
< = Not Detected at the numerical value shown. If present, result is less than this value.
[ ] = Result is estimated due to matrix interferences or calibration curve exceedence.

CHAIN-OF-CUSTODY is enclosed if received with your sample submission.

DRINKING WATER CERTIFICATIONS: Chemistry = C-71-02 Bacteriology = M-76-5

QUALITY ASSURANCE OFFICER

LABORATORY DIRECTOR

The data in this report has been reviewed and complies with EIS Quality Control unless specifically addressed above.

SAMPLE RESULTS

Client Name: J.F. New & Associates
Client Project: Littoral Zone Restoration

Report Date: 5/21/07
EIS Order No: 070400171

EIS Lab Number	Client Description	Sample Date	Parameter	Result	Units	RDL	Test Date	Analyst ID	Method
115180	Chapman	4/18/07	Moisture(%)	66	%	0.1	4/24/07	E21	160.3
		4/18/07	Nitrogen(Kjeldahl)Total	1850	mg/kg(wet)	140	5/3/07	E03	4500-NH3 C
		4/18/07	Phosphorus,Total	13	mg/kg(wet)	10	4/30/07	E03	4500-P D
115181	Wawasee	4/18/07	Moisture(%)	80	%	0.1	4/24/07	E21	160.3
		4/18/07	Nitrogen(Kjeldahl)Total	4580	mg/kg(wet)	140	5/3/07	E03	4500-NH3 C
		4/18/07	Phosphorus,Total	110	mg/kg(wet)	20	4/30/07	E03	4500-P D
115182	Tippecanoe	4/18/07	Moisture(%)	82	%	0.1	4/24/07	E21	160.3
		4/18/07	Nitrogen(Kjeldahl)Total	2040	mg/kg(wet)	140	5/3/07	E03	4500-NH3 C
		4/18/07	Phosphorus,Total	82	mg/kg(wet)	20	4/30/07	E03	4500-P D
115183	Crooked	4/19/07	Moisture(%)	26	%	0.1	4/24/07	E21	160.3
		4/19/07	Nitrogen(Kjeldahl)Total	1080	mg/kg(wet)	140	5/3/07	E03	4500-NH3 C
		4/19/07	Phosphorus,Total	110	mg/kg(wet)	20	4/30/07	E03	4500-P D

APPENDIX D:

PERMIT APPLICATIONS

LITTORAL ZONE RESTORATION RESEARCH PROJECT 2007-2009

CROOKED, CHAPMAN, TIPPECANOE, AND WAWASEE LAKES

STEUBEN AND KOSCIUSKO COUNTIES, INDIANA

STATE OF INDIANA
DEPARTMENT OF NATURAL RESOURCES

MAILED MAY 23 2007

CERTIFICATE OF APPROVAL
PUBLIC FRESHWATER LAKE

APPLICATION # : PL-20695

LAKE : Crooked Lake

APPLICANT : Crooked Lake Association
Keith Hoskins
801 West Coliseum Boulevard
Fort Wayne, IN 46808-1219

AGENT : JFNew
John Richardson
708 Roosevelt Road
Walkerton, IN 46574-1220

AUTHORITY : IC 14-26-2 with 312 IAC 11

DESCRIPTION : A ten (10) meter by one (1) meter area will be enclosed with orange snow fence and buoys will be placed to mark the research zone. Support poles will be placed at each corner of the enclosure. The support poles will be short (< 1 foot) rebar encased in a PVC sleeve with a PVC cap. Within the enclosure, four treatment types will be installed on the bottom of the lake. Treatment 1 will involve planting native plants directly into the lake bottom; treatment 2 will involve the placement of a pre-planted coconut net on the lake bottom; treatment 3 will be the staking of a pre-planted wooden pallet structure on the lake bottom; and treatment 4 will involve the placement of concrete cellular confinement planters directly on the lake bottom. Each treatment will cover one square meter and the enclosure will be monitored weekly by residents on the lake and monthly by JFNew biologists from May thru September. The research project will continue until 2009 at which time the enclosure will be removed. Details of the project are contained in information received electronically at the Division of Water on March 20, 2007 and in plans and information received at the Division of Water on March 27, 2007, March 28, 2007, April 16, 2007, May 2, 2007, May 3, 2007 and May 23, 2007.

LOCATION : Approximately 675' lakeward of the shoreline on the northeast side of Comfort Point and south of the Gaging Station near Angola, Pleasant Township, Steuben County
SE¼, NE¼, SE¼, Section 8, T 37N, R 13E, Angola West Quadrangle
UTM Coordinates: Downstream 4615598 North, 662361 East

APPROVED BY : James J. Hebenstreit
James J. Hebenstreit, PE, Assistant Director
Division of Water

APPROVED ON : May 23, 2007

Attachments: Notice Of Right To Administrative Review
General Conditions
Special Conditions
Service List

STATE OF INDIANA
DEPARTMENT OF NATURAL RESOURCES

NOTICE OF RIGHT TO ADMINISTRATIVE REVIEW

APPLICATION #: PL- 20695

This signed document constitutes the issuance of a permit by the Department of Natural Resources, subject to the conditions and limitations stated on the pages entitled "General Conditions" and "Special Conditions".

The permit or any of the conditions or limitations which it contains may be appealed by applying for administrative review. Such review is governed by the Administrative Orders and Procedures Act, IC 4-21.5, and the Department's rules pertaining to adjudicative proceedings, 312 IAC 3-1.

In order to obtain a review, a written petition must be filed with the Division of Hearings within 18 days of the mailing date of this notice. The petition should be addressed to:

Mr. Stephen L. Lucas, Director
Division of Hearings
Room W272
402 West Washington Street
Indianapolis, Indiana 46204

The petition must contain specific reasons for the appeal and indicate the portion or portions of the permit to which the appeal pertains.

If an appeal is filed, the final agency determination will be made by the Natural Resources Commission following a legal proceeding conducted before an Administrative Law Judge. The Department of Natural Resources will be represented by legal counsel.

STATE OF INDIANA
DEPARTMENT OF NATURAL RESOURCES

GENERAL CONDITIONS

APPLICATION #: PL- 20695

(1) If any archaeological artifacts or human remains are uncovered during construction, federal law and regulations (16 USC 470, et seq.; 36 CFR 800.11, et al) and State Law (IC 14-21-1) require that work must stop and that the discovery must be reported to the Division of Historic Preservation and Archaeology within 2 business days.

Division of Historic Preservation and Archaeology
Room W274
402 West Washington Street
Indianapolis, IN 46204

Telephone: (317) 232-1646, FAX: (317) 232-8036

(2) This permit must be posted and maintained at the project site until the project is completed.

(3) This permit does not relieve the permittee of the responsibility for obtaining additional permits, approvals, easements, etc. as required by other federal, state, or local regulatory agencies.These agencies include, but are not limited to:

Agency	Telephone Number
*US Army Corps of Engineers, Detroit District	(313) 226-6828
Steuben County Drainage Board	(260) 668-1000
Indiana Department of Environmental Management	(317) 233-8488 or (800) 451-6027
Local city or county planning or zoning commission	

(4) This permit must not be construed as a waiver of any local ordinance or other state or federal law.

(5) This permit does not relieve the permittee of any liability for the effects which the project may have upon the safety of the life or property of others.

(6) This permit may be revoked by the Department of Natural Resources for violation of any condition, limitation or applicable statute or rule.

(7) This permit shall not be assignable or transferable without the prior written approval of the Department of Natural Resources. To initiate a transfer contact:

Mr. Michael W. Neyer, PE, Director
Division of Water
Room W264
402 West Washington Street
Indianapolis, IN 46204

Telephone: (317) 232-4160, Toll Free: (877) 928-3755
FAX: (317) 233-4579

(8) The Department of Natural Resources shall have the right to enter upon the site of the permitted activity for the purpose of inspecting the authorized work.

(9) The receipt and acceptance of this permit by the applicant or authorized agent shall be considered as acceptance of the conditions and limitations stated on the pages entitled "General Conditions" and "Special Conditions".

STATE OF INDIANA
DEPARTMENT OF NATURAL RESOURCES

SPECIAL CONDITIONS

APPLICATION #: PL- 20695

PERMIT VALIDITY : This permit is valid for 24 months from the "Approved On" date shown on the first page. If work has not been completed by May 23, 2009 the permit will become void and a new permit will be required in order to continue work on the project.

This permit becomes effective 18 days after the "MAILED" date shown on the first page. If both a petition for review and a petition for a stay of effectiveness are filed before this permit becomes effective, any part of the permit that is within the scope of the petition for stay is stayed for an additional 15 days.

CONFORMANCE : Other than those measures necessary to satisfy the "General Conditions" and "Special Conditions", the project must conform to the information received by the Department of Natural Resources on: March 20, 2007, March 27, 2007, March 28, 2007, April 16, 2007, May 2, 2007, May 3, 2007 and May 23, 2007. Any deviation from the information must receive the prior written approval of the Department.

Number	Special Condition
(1)	the ten square meter area enclosed with orange snow fence must be marked with Inland Series Navigational Buoys at each corner
(2)	remove the support poles and snow fence at the end of the demonstration period

STATE OF INDIANA
DEPARTMENT OF NATURAL RESOURCES

SERVICE LIST

APPLICATION #: PL- 20695

Crooked Lake Association
Keith Hoskins
801 West Coliseum Boulevard
Fort Wayne, IN 46808-1219

JFNew
John Richardson
708 Roosevelt Road
Walkerton, IN 46574-1220

*US Army Corps of Engineers, Detroit District
John Konik
Regulatory Office
PO Box 1027
Detroit, MI 48231-1027

Steuben County Drainage Board
County Surveyor
County Office Building
317 South Wayne Street, Suite 3K
Angola, IN 46703-1958

Steuben County Lakes Council, Inc
Sue Myers, Secretary
207 South Wayne Street, Suite B
Angola, IN 46703-1936

Angola Plan Commission
210 North Public Square
Angola, IN 46703-1960

Indiana Department of Natural Resources
Division of Law Enforcement
North Region Headquarters Dist 2
1124 North Mexico Road
Peru, IN 46970-7522

Steuben County Plan Commission
317 South Wayne Street
Suite 3-L
Angola, IN 46703-1966

Steuben County Soil and Water Conservation District
Peachtree Plaza 200
1220 North 200 West
Angola, IN 46703-9171

Staff Assignment:

Administrative	: R. Tony Scott, CFM
Technical	: R. Tony Scott, CFM
Environmental	: Christie L. Stanifer

MAILED MAY 17 2007

STATE OF INDIANA
DEPARTMENT OF NATURAL RESOURCES

CERTIFICATE OF APPROVAL
PUBLIC FRESHWATER LAKE

APPLICATION # : PL-20694

LAKE : Big Chapman Lake

APPLICANT : Chapman Lakes Foundation
Tom Ross
1389 Chapman Lake Drive
Warsaw, IN 46582-7807

AGENT : JFNew
John Richardson
708 Roosevelt Road
Walkerton, IN 46574-1220

AUTHORITY : IC 14-26-2 with 312 IAC 11

DESCRIPTION : A ten (10) meter by one (1) meter area will be enclosed with orange snow fence and buoys will be placed to mark the research zone. Support poles will be placed at each corner of the enclosure. The support poles will be short (< 1 foot) rebar encased in a PVC sleeve with a PVC cap. Within the enclosure, four treatment types will be installed on the bottom of the lake. Treatment 1 will involve planting native plants directly into the lake bottom; treatment 2 will involve the placement of a pre-planted coconut net on the lake bottom; treatment 3 will be the staking of a pre-planted wooden pallet structure on the lake bottom; and treatment 4 will involve the placement of concrete cellular confinement planters directly on the lake bottom. Each treatment will cover one square meter and the enclosure will be monitored weekly by residents on the lake and monthly by JFNew biologists from May thru September. The research project will continue until 2009 at which time the enclosure will be removed. Details of the project are contained in information received electronically at the Division of Water on March 20, 2007 and in plans and information received at the Division of Water on March 27, 2007, March 28, 2007, April 16, 2007 and May 2, 2007.

LOCATION : About 60 feet south of the shoreline of Lot 67 in Chapman's Lake Park Subdivision near Leesburg, Plain Township, Kosciusko County
SE¼, SW¼, NE¼, Section 26, T 33N, R 6E, Leesburg Quadrangle
UTM Coordinates: Downstream 4571233 North, 601231 East

APPROVED BY : J. J. Hebenstreit
James J. Hebenstreit, PE, Assistant Director
Division of Water

APPROVED ON : May 17, 2007

Attachments: Notice Of Right To Administrative Review
General Conditions
Special Conditions
Service List

STATE OF INDIANA
DEPARTMENT OF NATURAL RESOURCES

NOTICE OF RIGHT TO ADMINISTRATIVE REVIEW

APPLICATION #: PL- 20694

This signed document constitutes the issuance of a permit by the Department of Natural Resources, subject to the conditions and limitations stated on the pages entitled "General Conditions" and "Special Conditions".

The permit or any of the conditions or limitations which it contains may be appealed by applying for administrative review. Such review is governed by the Administrative Orders and Procedures Act, IC 4-21.5, and the Department's rules pertaining to adjudicative proceedings, 312 IAC 3-1.

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If an appeal is filed, the final agency determination will be made by the Natural Resources Commission following a legal proceeding conducted before an Administrative Law Judge. The Department of Natural Resources will be represented by legal counsel.

STATE OF INDIANA
DEPARTMENT OF NATURAL RESOURCES

GENERAL CONDITIONS

APPLICATION #: PL- 20694

(1) If any archaeological artifacts or human remains are uncovered during construction, federal law and regulations (16 USC 470, et seq.; 36 CFR 800.11, et al) and State Law (IC 14-21-1) require that work must stop and that the discovery must be reported to the Division of Historic Preservation and Archaeology within 2 business days.

Division of Historic Preservation and Archaeology
Room W274
402 West Washington Street
Indianapolis, IN 46204

Telephone: (317) 232-1646, FAX: (317) 232-8036

(2) This permit must be posted and maintained at the project site until the project is completed.

(3) This permit does not relieve the permittee of the responsibility for obtaining additional permits, approvals, easements, etc. as required by other federal, state, or local regulatory agencies.These agencies include, but are not limited to:

Agency	Telephone Number
*US Army Corps of Engineers, Louisville District	(502) 315-6733
Indiana Department of Environmental Management	(317) 233-8488 or (800) 451-6027
Local city or county planning or zoning commission	

(4) This permit must not be construed as a waiver of any local ordinance or other state or federal law.

(5) This permit does not relieve the permittee of any liability for the effects which the project may have upon the safety of the life or property of others.

(6) This permit may be revoked by the Department of Natural Resources for violation of any condition, limitation or applicable statute or rule.

(7) This permit shall not be assignable or transferable without the prior written approval of the Department of Natural Resources. To initiate a transfer contact:

Mr. Michael W. Neyer, PE, Director
Division of Water
Room W264
402 West Washington Street
Indianapolis, IN 46204

Telephone: (317) 232-4160, Toll Free: (877) 928-3755
FAX: (317) 233-4579

(8) The Department of Natural Resources shall have the right to enter upon the site of the permitted activity for the purpose of inspecting the authorized work.

(9) The receipt and acceptance of this permit by the applicant or authorized agent shall be considered as acceptance of the conditions and limitations stated on the pages entitled "General Conditions" and "Special Conditions".

STATE OF INDIANA
DEPARTMENT OF NATURAL RESOURCES

SPECIAL CONDITIONS

APPLICATION #: PL- 20694

PERMIT VALIDITY : This permit is valid for 24 months from the "Approved On" date shown on the first page. If work has not been completed by May 17, 2009 the permit will become void and a new permit will be required in order to continue work on the project.

This permit becomes effective 18 days after the "MAILED" date shown on the first page. If both a petition for review and a petition for a stay of effectiveness are filed before this permit becomes effective, any part of the permit that is within the scope of the petition for stay is stayed for an additional 15 days.

CONFORMANCE : Other than those measures necessary to satisfy the "General Conditions" and "Special Conditions", the project must conform to the information received by the Department of Natural Resources on: March 20, 2007, March 27, 2007, March 28, 2007, April 16, 2007 and May 2, 2007. Any deviation from the information must receive the prior written approval of the Department.

Number	Special Condition
(1)	remove the support poles and snow fence at the end of the demonstration period
(2)	the ten square meter area enclosed with orange snow fence must be marked with Inland Series Navigational Buoys at each corner

STATE OF INDIANA
DEPARTMENT OF NATURAL RESOURCES

SERVICE LIST

APPLICATION #: PL- 20694

Chapman Lakes Foundation
Tom Ross
1389 Chapman Lake Drive
Warsaw, IN 46582-7807

JFNew
John Richardson
708 Roosevelt Road
Walkerton, IN 46574-1220

*US Army Corps of Engineers, Louisville District
Jim Townsend
Regulatory Functions Branch
PO Box 59
Louisville, KY 40201-0059

Indiana Department of Natural Resources
Division of Law Enforcement
North Region Headquarters Dist 1
1124 North Mexico Road
Peru, IN 46970-7522

Kosciusko County Area Plan Commission
Court House, 1st Floor, Room 26
100 West Center Street
Warsaw, IN 46580-2872

Kosciusko County Soil and Water Conservation District
217 Bell Drive
Warsaw, IN 46580-9362

Staff Assignment:

Administrative	: R. Tony Scott, CFM
Technical	: R. Tony Scott, CFM
Environmental	: Christie L. Stanifer

STATE OF INDIANA
DEPARTMENT OF NATURAL RESOURCES

CERTIFICATE OF APPROVAL
PUBLIC FRESHWATER LAKE

MAILED MAY 17 2007

APPLICATION # : PL-20697

LAKE : Tippecanoe Lake

APPLICANT : Tippecanoe Environmental Lake and Watershed Foundation
Holly LaSalle
67 EMS T79A Lane
Syracuse, IN 46567

AGENT : JFNew
John Richardson
708 Roosevelt Road
Walkerton, IN 46574-1220

AUTHORITY : IC 14-26-2 with 312 IAC 11

DESCRIPTION : A ten (10) meter by one (1) meter area will be enclosed with orange snow fence and buoys will be placed to mark the research zone. Support poles will be placed at each corner of the enclosure. The support poles will be short (< 1 foot) rebar encased in a PVC sleeve with a PVC cap. Within the enclosure, four treatment types will be installed on the bottom of the lake. Treatment 1 will involve planting native plants directly into the lake bottom; treatment 2 will involve the placement of a pre-planted coconut net on the lake bottom; treatment 3 will be the staking of a pre-planted wooden pallet structure on the lake bottom; and treatment 4 will involve the placement of concrete cellular confinement planters directly on the lake bottom. Each treatment will cover one square meter and the enclosure will be monitored weekly by residents on the lake and monthly by JFNew biologists from May thru September. The research project will continue until 2009 at which time the enclosure will be removed. Details of the project are contained in information received electronically at the Division of Water on March 20, 2007 and in plans and information received at the Division of Water on March 27, 2007, March 28, 2007, April 16, 2007 and May 2, 2007.

LOCATION : Along the eastern shore of Tippecanoe Lake a little north of the center, near the channel connecting Tippecanoe Lake to James Lake near Leesburg, Tippecanoe Township, Kosciusko County
SW¼, SW¼, SE¼, Section 17, T 33N, R 7E, North Webster Quadrangle
UTM Coordinates: Downstream 4575388 North, 605579 East

APPROVED BY : James J. Hebenstreit
James J. Hebenstreit, PE, Assistant Director
Division of Water

APPROVED ON : May 17, 2007

Attachments: Notice Of Right To Administrative Review
General Conditions
Special Conditions
Service List

STATE OF INDIANA
DEPARTMENT OF NATURAL RESOURCES

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STATE OF INDIANA
DEPARTMENT OF NATURAL RESOURCES

GENERAL CONDITIONS

APPLICATION #: PL- 20697

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Division of Historic Preservation and Archaeology
Room W274
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Room W264
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Indianapolis, IN 46204

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STATE OF INDIANA
DEPARTMENT OF NATURAL RESOURCES

SPECIAL CONDITIONS

APPLICATION #: PL- 20697

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STATE OF INDIANA
DEPARTMENT OF NATURAL RESOURCES

SERVICE LIST

APPLICATION #: PL- 20697

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Holly LaSalle
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Division of Law Enforcement
North Region Headquarters Dist 1
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Kosciusko County Area Plan Commission
Court House, 1st Floor, Room 26
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217 Bell Drive
Warsaw, IN 46580-9362

Staff Assignment:

Administrative	: R. Tony Scott, CFM
Technical	: R. Tony Scott, CFM
Environmental	: Christie L. Stanifer

STATE OF INDIANA
DEPARTMENT OF NATURAL RESOURCES

CERTIFICATE OF APPROVAL
PUBLIC FRESHWATER LAKE

MAILED MAY 17 2007

APPLICATION # : PL-20696

LAKE : Lake Wawasee

APPLICANT : Wawasee Area Conservancy Foundation
Heather Harwood
13265 North Eastshore Drive
Syracuse, IN 46567-8460

AGENT : JFNew
John Richardson
708 Roosevelt Road
Walkerton, IN 46574-1220

AUTHORITY : IC 14-26-2 with 312 IAC 11

DESCRIPTION : A ten (10) meter by one (1) meter area will be enclosed with orange snow fence and buoys will be placed to mark the research zone. Support poles will be placed at each corner of the enclosure. The support poles will be short (< 1 foot) rebar encased in a PVC sleeve with a PVC cap. Within the enclosure, four treatment types will be installed on the bottom of the lake. Treatment 1 will involve planting native plants directly into the lake bottom; treatment 2 will involve the placement of a pre-planted coconut net on the lake bottom; treatment 3 will be the staking of a pre-planted wooden pallet structure on the lake bottom; and treatment 4 will involve the placement of concrete cellular confinement planters directly on the lake bottom. Each treatment will cover one square meter and the enclosure will be monitored weekly by residents on the lake and monthly by JFNew biologists from May thru September. The research project will continue until 2009 at which time the enclosure will be removed. Details of the project are contained in information received electronically at the Division of Water on March 20, 2007 and in plans and information received at the Division of Water on March 27, 2007, March 28, 2007, April 16, 2007 and May 2, 2007.

LOCATION : The northwest corner of Lake Wawasee in Conklin Bay near Syracuse, Turkey Creek Township, Kosciusko County
NW¼, SE¼, NW¼, Section 17, T 34N, R 7E, Lake Wawasee Quadrangle
UTM Coordinates: Downstream 4584325 North, 605051 East

APPROVED BY : J. Hebenstreit
James J. Hebenstreit, PE, Assistant Director
Division of Water

APPROVED ON : May 17, 2007

Attachments: Notice Of Right To Administrative Review
General Conditions
Special Conditions
Service List

STATE OF INDIANA
DEPARTMENT OF NATURAL RESOURCES

NOTICE OF RIGHT TO ADMINISTRATIVE REVIEW

APPLICATION #: PL- 20696

This signed document constitutes the issuance of a permit by the Department of Natural Resources, subject to the conditions and limitations stated on the pages entitled "General Conditions" and "Special Conditions".

The permit or any of the conditions or limitations which it contains may be appealed by applying for administrative review. Such review is governed by the Administrative Orders and Procedures Act, IC 4-21.5, and the Department's rules pertaining to adjudicative proceedings, 312 IAC 3-1.

In order to obtain a review, a written petition must be filed with the Division of Hearings within 18 days of the mailing date of this notice. The petition should be addressed to:

Mr. Stephen L. Lucas, Director
Division of Hearings
Room W272
402 West Washington Street
Indianapolis, Indiana 46204

The petition must contain specific reasons for the appeal and indicate the portion or portions of the permit to which the appeal pertains.

If an appeal is filed, the final agency determination will be made by the Natural Resources Commission following a legal proceeding conducted before an Administrative Law Judge. The Department of Natural Resources will be represented by legal counsel.

STATE OF INDIANA
DEPARTMENT OF NATURAL RESOURCES

GENERAL CONDITIONS

APPLICATION #: PL- 20696

(1) If any archaeological artifacts or human remains are uncovered during construction, federal law and regulations (16 USC 470, et seq.; 36 CFR 800.11, et al) and State Law (IC 14-21-1) require that work must stop and that the discovery must be reported to the Division of Historic Preservation and Archaeology within 2 business days.

Division of Historic Preservation and Archaeology
Room W274
402 West Washington Street
Indianapolis, IN 46204

Telephone: (317) 232-1646, FAX: (317) 232-8036

(2) This permit must be posted and maintained at the project site until the project is completed.

(3) This permit does not relieve the permittee of the responsibility for obtaining additional permits, approvals, easements, etc. as required by other federal, state, or local regulatory agencies.These agencies include, but are not limited to:

Agency	Telephone Number
*US Army Corps of Engineers, Detroit District	(313) 226-6828
Indiana Department of Environmental Management	(317) 233-8488 or (800) 451-6027
Local city or county planning or zoning commission	

(4) This permit must not be construed as a waiver of any local ordinance or other state or federal law.

(5) This permit does not relieve the permittee of any liability for the effects which the project may have upon the safety of the life or property of others.

(6) This permit may be revoked by the Department of Natural Resources for violation of any condition, limitation or applicable statute or rule.

(7) This permit shall not be assignable or transferable without the prior written approval of the Department of Natural Resources. To initiate a transfer contact:

Mr. Michael W. Neyer, PE, Director
Division of Water
Room W264
402 West Washington Street
Indianapolis, IN 46204

Telephone: (317) 232-4160, Toll Free: (877) 928-3755
FAX: (317) 233-4579

(8) The Department of Natural Resources shall have the right to enter upon the site of the permitted activity for the purpose of inspecting the authorized work.

(9) The receipt and acceptance of this permit by the applicant or authorized agent shall be considered as acceptance of the conditions and limitations stated on the pages entitled "General Conditions" and "Special Conditions".

STATE OF INDIANA
DEPARTMENT OF NATURAL RESOURCES

SPECIAL CONDITIONS

APPLICATION #: PL- 20696

PERMIT VALIDITY : This permit is valid for 24 months from the "Approved On" date shown on the first page. If work has not been completed by May 17, 2009 the permit will become void and a new permit will be required in order to continue work on the project.

This permit becomes effective 18 days after the "MAILED" date shown on the first page. If both a petition for review and a petition for a stay of effectiveness are filed before this permit becomes effective, any part of the permit that is within the scope of the petition for stay is stayed for an additional 15 days.

CONFORMANCE : Other than those measures necessary to satisfy the "General Conditions" and "Special Conditions", the project must conform to the information received by the Department of Natural Resources on: March 20, 2007, March 27, 2007, March 28, 2007, April 16, 2007 and May 2, 2007. Any deviation from the information must receive the prior written approval of the Department.

Number	Special Condition
(1)	remove the support poles and snow fence at the end of the demonstration period
(2)	the ten square meter area enclosed with orange snow fence must be marked with Inland Series Navigational Buoys at each corner

STATE OF INDIANA
DEPARTMENT OF NATURAL RESOURCES

SERVICE LIST

APPLICATION #: PL- 20696

Wawasee Area Conservancy Foundation
Heather Harwood
13265 North Eastshore Drive
Syracuse, IN 46567-8460

JFNew
John Richardson
708 Roosevelt Road
Walkerton, IN 46574-1220

*US Army Corps of Engineers, Detroit District
John Konik
Regulatory Office
PO Box 1027
Detroit, MI 48231-1027

Indiana Department of Natural Resources
Division of Law Enforcement
North Region Headquarters Dist 1
1124 North Mexico Road
Peru, IN 46970-7522

Kosciusko County Area Plan Commission
Court House, 1st Floor, Room 26
100 West Center Street
Warsaw, IN 46580-2872

Kosciusko County Soil and Water Conservation District
217 Bell Drive
Warsaw, IN 46580-9362

Staff Assignment:

Administrative	: R. Tony Scott, CFM
Technical	: R. Tony Scott, CFM
Environmental	: Christie L. Stanifer

APPENDIX E:

PRE-PLANTING PHOTOGRAPHS OF PLANTED SPECIES

LITTORAL ZONE RESTORATION RESEARCH PROJECT 2007-2009

CROOKED, CHAPMAN, TIPPECANOE, AND WAWASEE LAKES

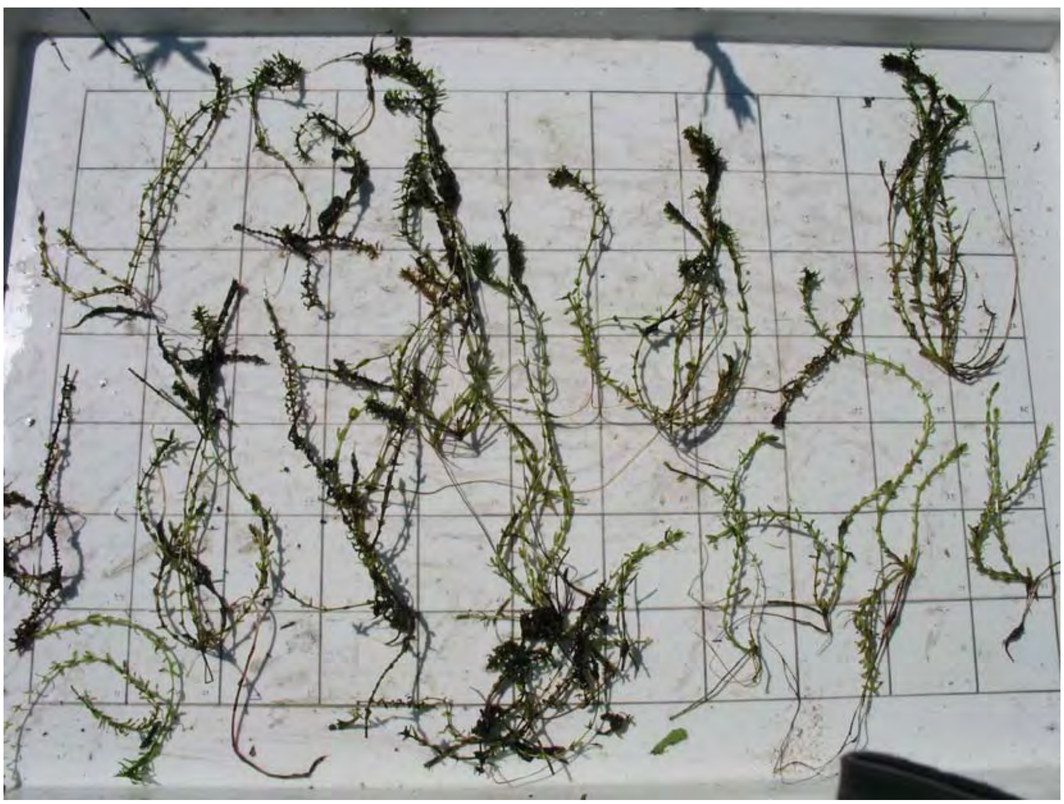
STEUBEN AND KOSCIUSKO COUNTIES, INDIANA

Illinois pondweed *(Potamogeton illinoensis).*

Grassy pondweed *(Potamogeton gramineus).*

JFNew
708 Roosevelt Road, Walkerton, IN 46574
Phone 574-586-3400 / Fax 574-586-3446
www.jfnew.com

Eel grass *(Vallisneria americana).*



Common waterweed *(Elodea canadensis).*

Aquatic Plant Species: Pre-planting

JFNew #061055.00

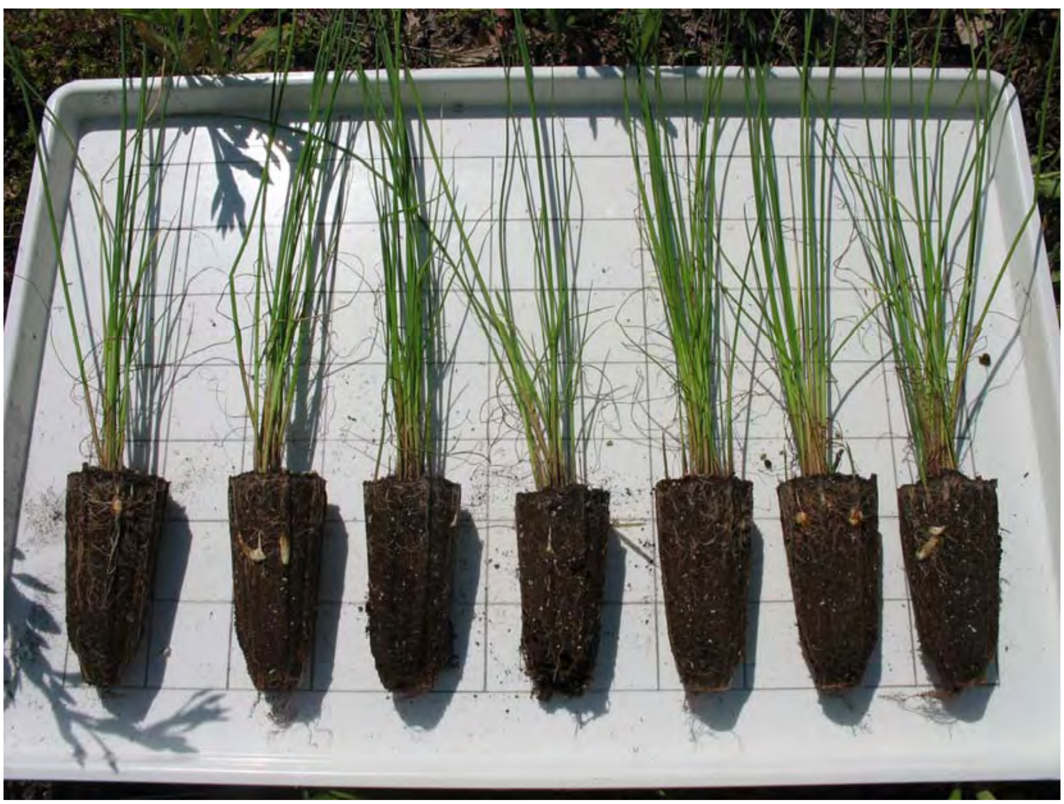
JFNew
708 Roosevelt Road, Walkerton, IN 46574
Phone 574-586-3400 / Fax 574-586-3446
www.jfnew.com

Watershield *(Brasenia shreberi).*

White water lily *(Nymphaea tuberosa).*

Aquatic Plant Species: Pre-planting	JFNew #061055.00	JFNew 708 Roosevelt Road, Walkerton, IN 46574 Phone 574-586-3400 / Fax 574-586-3446 www.jfnew.com

Hard-stem bulrush *(Scirpus pungens).*



Chairmaker's rush *(Scirpus acutus).*

JFNew

708 Roosevelt Road, Walkerton, IN 46574
Phone 574-586-3400 / Fax 574-586-3446
www.jfnew.com

Pickerel weed *(Pontedaria cordata).*

JFNew
708 Roosevelt Road, Walkerton, IN 46574
Phone 574-586-3400 / Fax 574-586-3446
www.jfnew.com

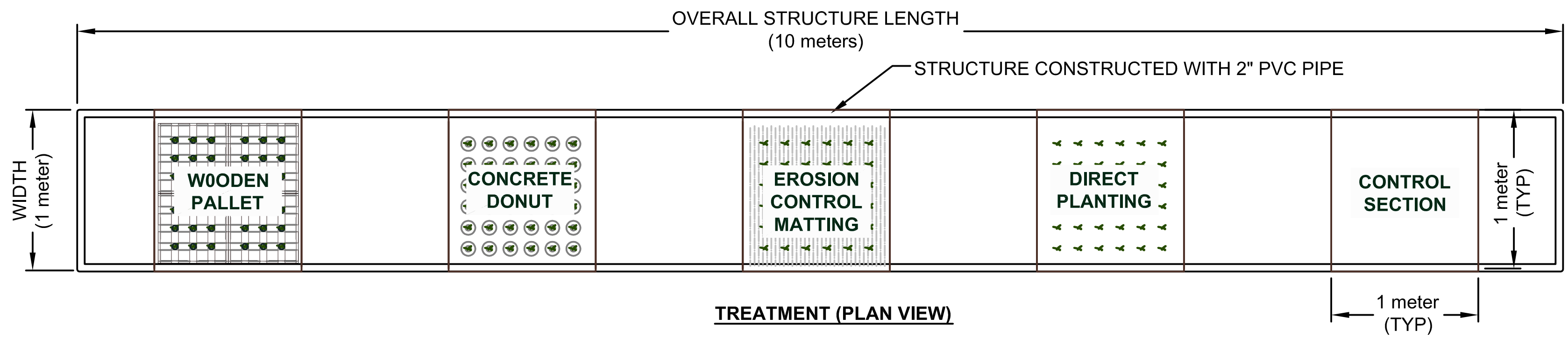
APPENDIX F:

TREATMENT DESIGN DRAWINGS

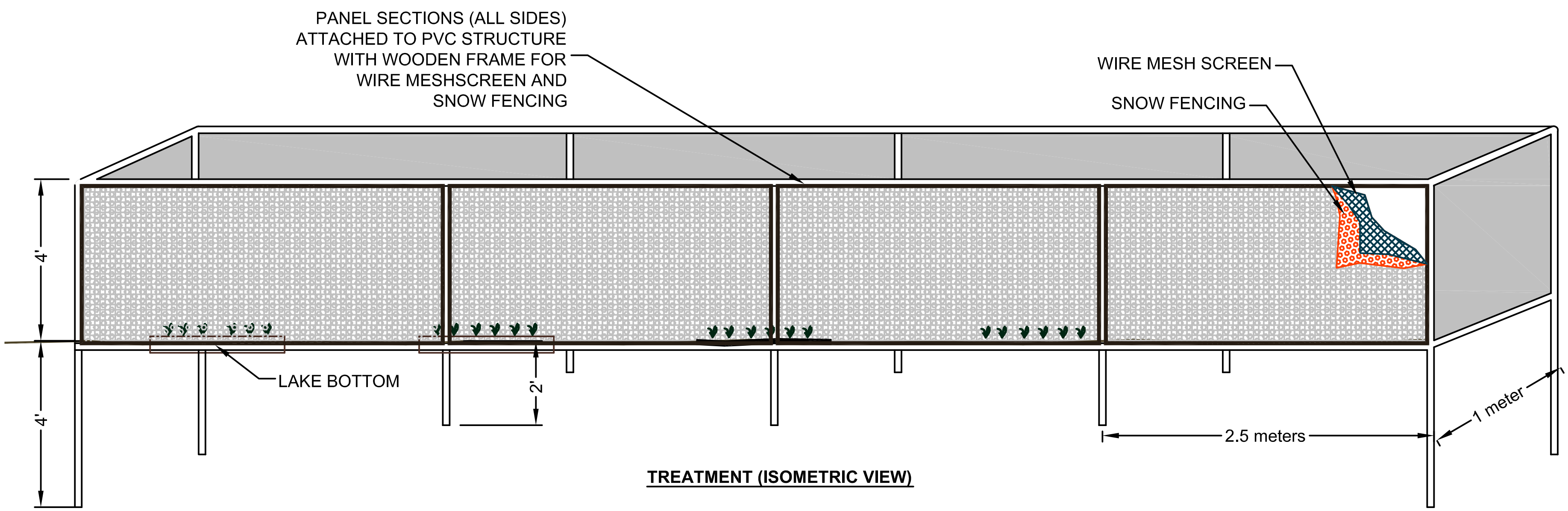
LITTORAL ZONE RESTORATION RESEARCH PROJECT 2007-2009

CROOKED, CHAPMAN, TIPPECANOE, AND WAWASEE LAKES

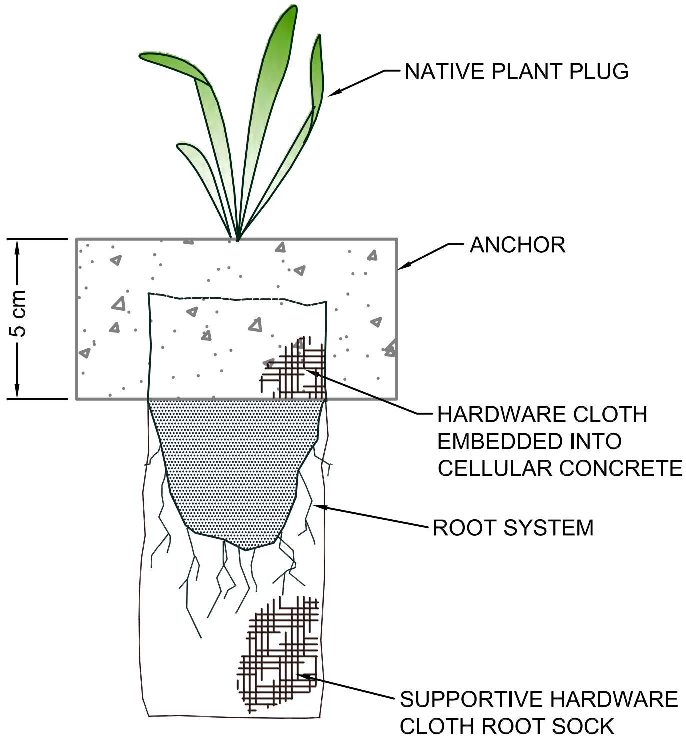
STEUBEN AND KOSCIUSKO COUNTIES, INDIANA



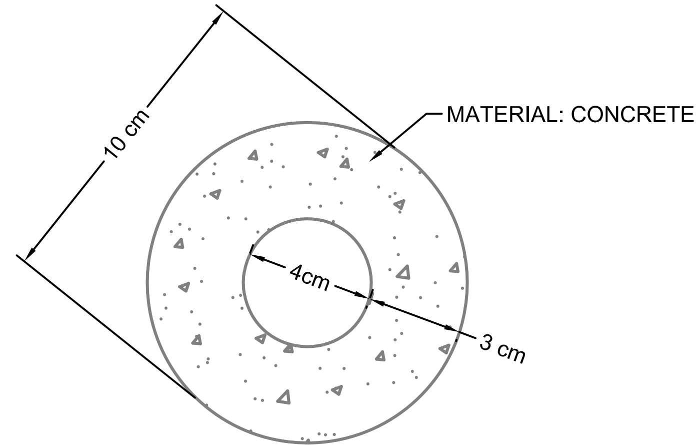
TREATMENT (PLAN VIEW)



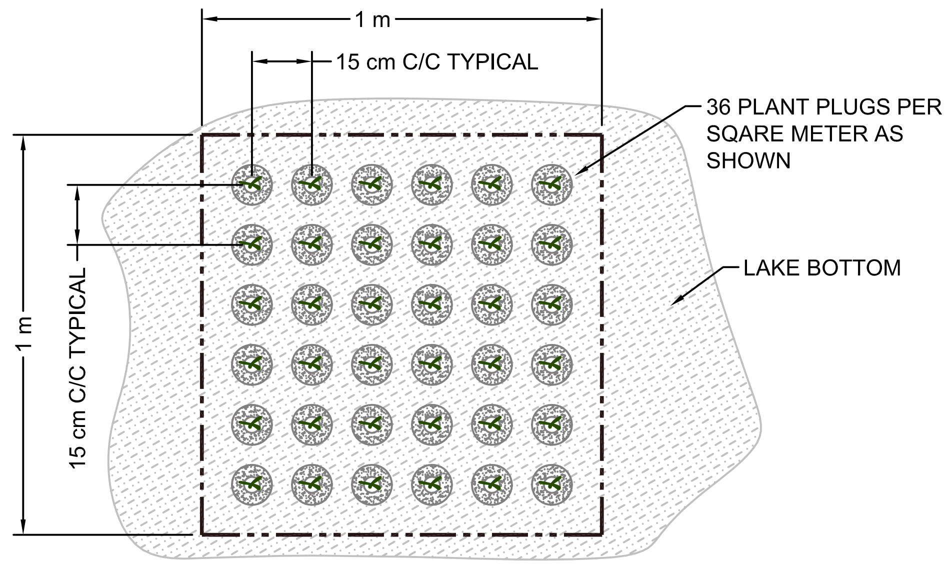
TREATMENT (ISOMETRIC VIEW)



PROFILE



ANCHOR PLAN VIEW



TREATMENT PLAN VIEW

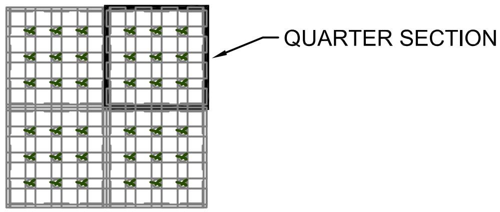
Cellular Concrete Structure
Littoral Zone Restoration Research Project

NOT TO SCALE

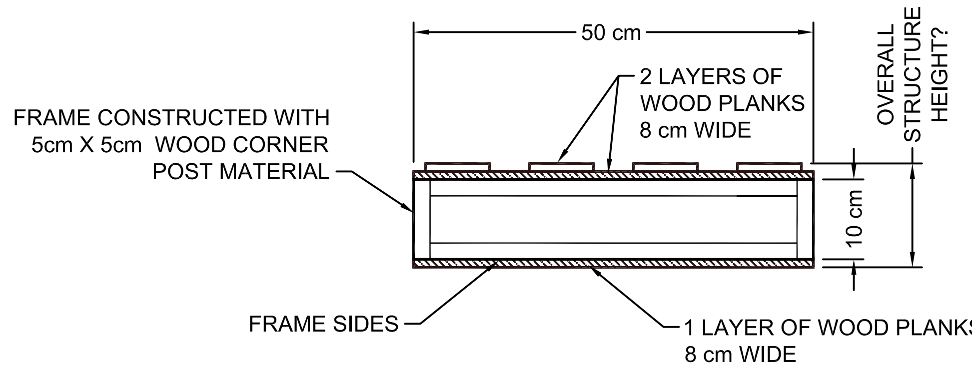
JFNew #061055.00

JFNew

708 Roosevelt Road, Walkerton, IN 46574
Phone 574-586-3400 / Fax 574-586-3446
www.jfnew.com

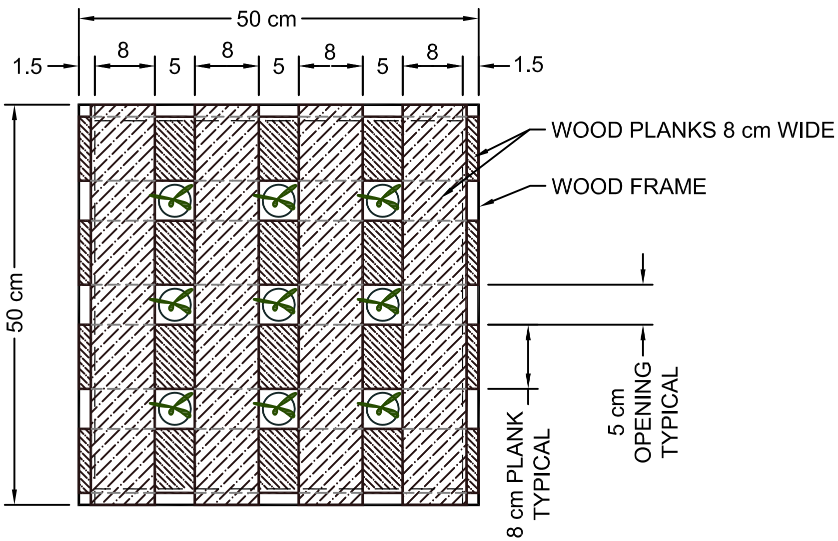


TREATMENT PLAN VIEW

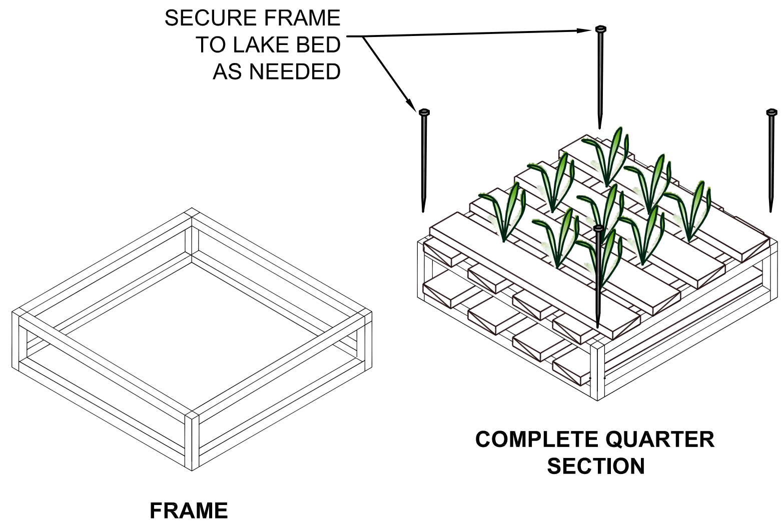


TYPICAL ELEVATION QUARTER SECTION

NOTE:
1. QUARTER SECTION SHALL BE CREATED IN A SYMMETRICAL FASHION TO CONTAIN 9 PLANT PLUGS AS SHOWN.
2. TREATED LUMBER IS NOT ACCEPTABLE



PLAN VIEW QUARTER SECTION



ISOMETRIC VIEWS

Wood Anchor Structure
Littoral Zone Restoration Research Project

NOT TO SCALE

JFNew #061055.00

JFNew
708 Roosevelt Road, Walkerton, IN 46574
Phone 574-586-3400 / Fax 574-586-3446
www.jfnew.com

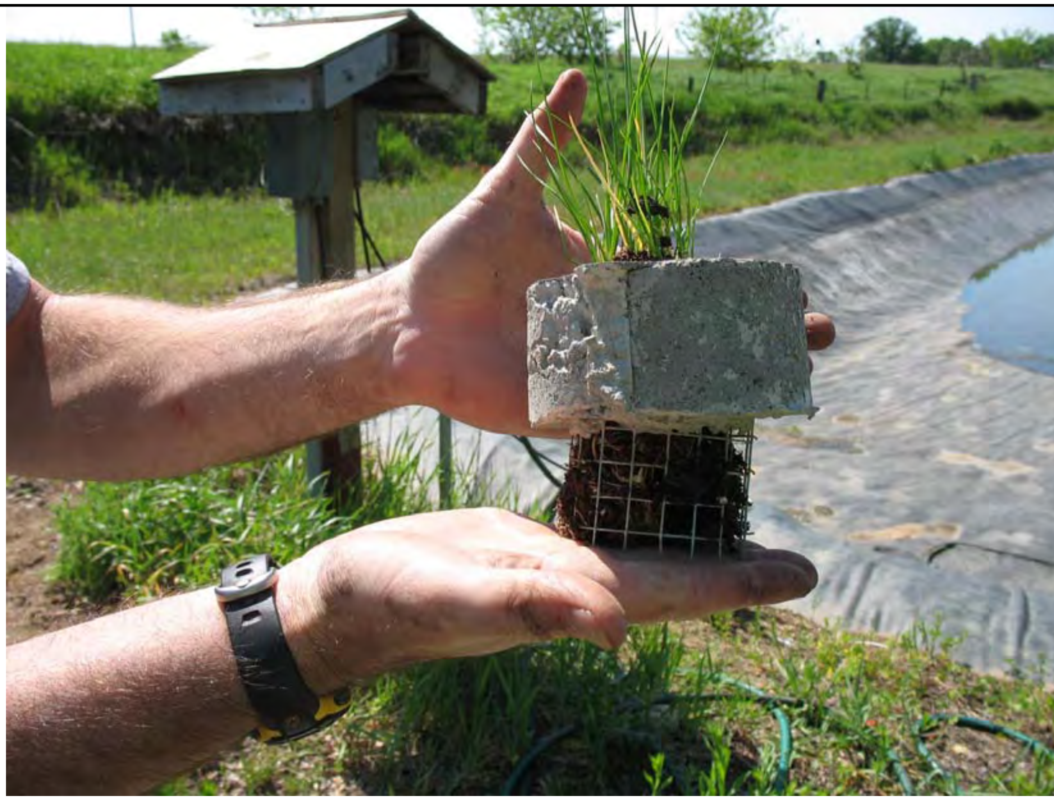
APPENDIX G:

TREATMENT INSTALLATION PHOTOS

LITTORAL ZONE RESTORATION RESEARCH PROJECT 2007-2009

CROOKED, CHAPMAN, TIPPECANOE, AND WAWASEE LAKES

STEUBEN AND KOSCIUSKO COUNTIES, INDIANA



Planted concrete treatment (1 of 36 per treatment) prior to incubation period.

Planted concrete treatment prior to installation in the treatment at Chapman Lake.

Aquatic Plant Species: Pre-planting	JFNew #061055.00	JFNew 708 Roosevelt Road, Walkerton, IN 46574 Phone 574-586-3400 / Fax 574-586-3446 www.jfnew.com

Wooden structure planting prior to incubation period. One set of four "crates" equals one treatment

Planted wooden treatment prior to installation in the treatment at Lake Wawasee.

Aquatic Plant Species: Pre-planting	JFNew #061055.00	708 Roosevelt Road, Walkerton, IN 46574 Phone 574-586-3400 / Fax 574-586-3446 www.jfnew.com

Coconut fabric planting prior to installation in Lake Tippecanoe.

Coconut fabric staking during installation at Lake Tippecanoe.

JFNew
708 Roosevelt Road, Walkerton, IN 46574
Phone 574-586-3400 / Fax 574-586-3446
www.jfnew.com

APPENDIX H:

MONITORING DATA SHEETS

LITTORAL ZONE RESTORATION RESEARCH PROJECT 2007-2009

CROOKED, CHAPMAN, TIPPECANOE, AND WAWASEE LAKES

STEUBEN AND KOSCIUSKO COUNTIES, INDIANA

Littoral Zone Monitoring Data Sheet

Lake:
County:
Date:
Initials:

General Site Notes:

Please answer each question below by highlighting the correct response.

1. Are the buoys missing? Yes No
   There should be 1 small one at each corner and 1 large one marking the area from the lake side.
   a. If so, where: ____

2. Are any of the PVC pipes broken? Yes No
   a. If so, where: ____

3. Are there any gaps in the exclosure? Yes No
   a. If so, where: ____

4. Do the plants appear to be healthy? Yes No

5. What is the transparency in the deepest point of the lake? _________________

Submit completed report to Aaron Johnson at ajohnson@jfnew.com. Contact Aaron directly if there are structural problems at 574.586.3400 or 574.229.8749.

Return to: Aaron Johnson at ajohnson@jfnew.com. Contact via phone at 574.586.3400 or 574.229.8749 (cell) if issues arise between weekly monitoring.

Lake ____________ Investigator(s) ______________________________ Date ________

Treatment/Control ______________________________

Species	#	Present/Absent	Height/Length	Flowering/Fruiting
Brasenia schreberi	1			
	2			
	3			
	4			
Elodea canadensis	1			
	2			
	3			
	4			
Nymphaea tuberosa	1			
	2			
	3			
	4			
Pontederia cordata	1			
	2			
	3			
	4			
Potamogeton gramineus	1			
	2			
	3			
	4			
Potamogeton illinoensis	1			
	2			
	3			
	4			
Scirpus acutus	1			
	2			
	3			
	4			
Scirpus pungens	1			
	2			
	3			
	4			
Vallisneria americana	1			
	2			
	3			
	4			

Lake ____________________ Investigator(s) ____ Date ___________

Treatment/Control ____

Additional Species (include volunteers of those species planted) # stems

Notes: